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DEPARTMENTS

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Materials BRIEFS

Grease Carrier

Nylon tubing is used on the push button lubrication system on Lincolns and Mercurys. Ninety feet of 1/8-in. tube feeds 12 lubrication points simultaneously. Tube has burst strength of 2500 psi.

On the Skids

Skis coated with fluorocarbon resin have 30 to 50% less friction on snow. ICI, the resin supplier, adds that the skis are "safer on poor snow". There is still time to try it out at Tuckerman's.

Whose Boom?

Despite the housing boom of 1954, more glass was used for automobile windows and windshields than the total used in residential glazing.

Film Base

A photographic film base of polystyrene is now available for some critical photographic applications requiring accurate register. The 0.005-in. base is about three times as dimensionally stable as cellulose ester film.

Squeezable Label

A label that squeezes along with the bottle has been developed for polyethylene containers. The flexible label gives with the base material and returns to its original shape when pressure is released.

Canned Ammonia

Household ammonia is now sold in metal cans for the first time in packaging history. The can has cemented side seams, is tinless with a screw top plastic cap and aluminum nozzle.

Unlucky?

The United States ranks 13th among the national standards organizations of 34 nations in degree of participation in international standards work.

Men of Materials...

their views
on development
and utilization
of engineering materials
in industry

J. H. Du Bois
Vice President Engineering
Mycalex Corporation of America

Broad experience in sales, new product development, and management as well as engineering has provided J. H. Du Bois a valuable background in the many aspects of the plastics industry. He began his career as an engineer and sales engineer for General Electric. In 1944 he took the position of Executive Engineer with Shaw Insulator, becoming a vice president of that organization in 1949. He was elected national president of the Society of Plastics Engineers in 1947. Since 1952 he has held his present position with Mycalex. He is author of *Plastics*, a text that has enjoyed three editions, and his papers have been incorporated in numerous reference works. He is a frequent contributor to the technical press.

"The plastics materials require careful, knowledgeable selection to obtain the most useful balance of properties. Each type of plastics material, significantly, exhibits certain desirable features, but usually at the sacrifice of some other consideration, either in physical or mechanical properties, or material cost.

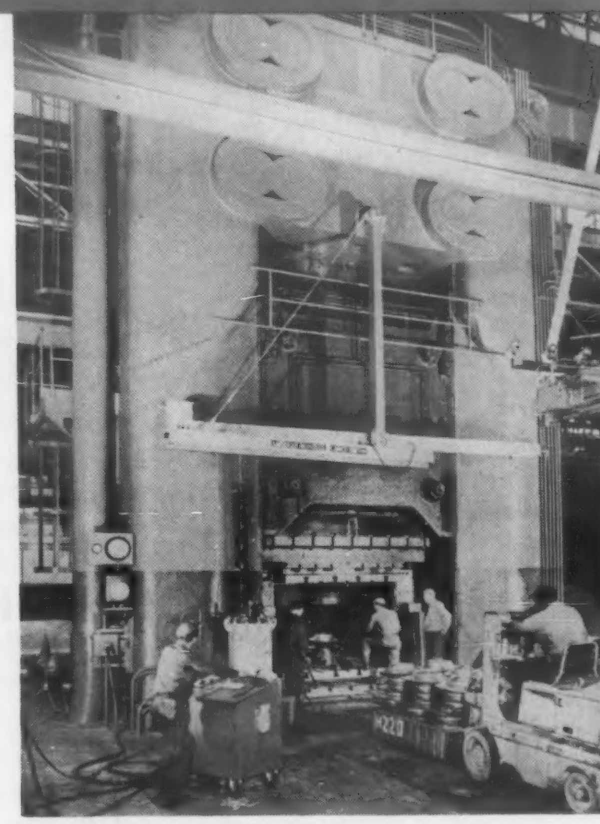
"This is not to say that plastics cannot fulfill many important requisites in terms of special electrical, thermal expansion, tactile, thermal insulating, flexural, expansion, and inertia properties. They can. And they offer attractive colors, textures, optical clarity, reproducibility, damping capacity and many other useful attributes from an engineering and production point of view. But it is seldom possible to have all these desirable properties in a single plastics material.

"Selecting the proper plastics, then, resolves into an evaluation of the important values and weaknesses found in each type. Most failures—attributed to "plastics"—have resulted from incomplete knowledge of operating conditions or lack of consideration for the limitations of the material selected. The plastics engineer responsible for materials selection must familiarize himself with all possible operating conditions that his product will encounter. In critical applications a handmade sample should be run to destruction. Since no single material can have all the positive qualities, the negative aspects must be compensated in the product design.

"Cost is always a final consideration in the production of any product. But cost per pound of material is not a valid barometer. Bear in mind that the most costly material always is the wrong material."

MATERIALS ENGINEERING News Digest

***Forged spoke wheels** of aluminum for passenger cars is the first civilian job Alcoa's 8000-ton forging press has turned out.*



***Super-rigid** 8000-ton forging press weighs almost 4,000,000 lb. Note shrink links used to join castings that form main body of press.*

Heavy Presses Near Completion

The construction story of the Air Force heavy press program is now in its closing stages. The time is approaching when forgings and extrusions of a size commensurate with the presses will be available. The question is whether there will be enough demand from civilian markets to keep the big presses punching.

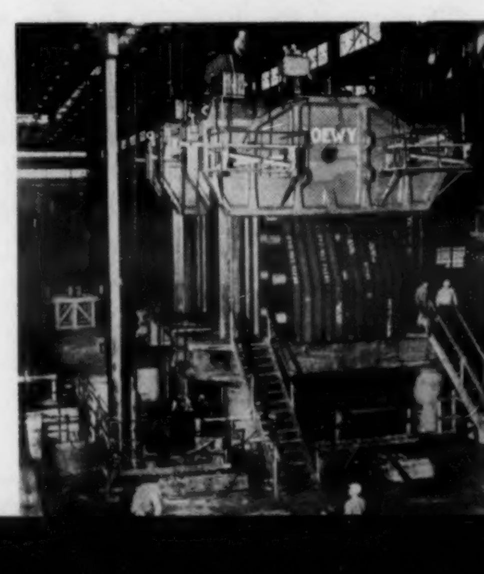
Alcoa's 8000-ton forging press in Cleveland has been pounding out forged aluminum spoked wheels for Cadillacs. The aluminum wheel, according to Alcoa and General Motors, is extremely strong and lightweight. The surface is suitable for chromium plating.

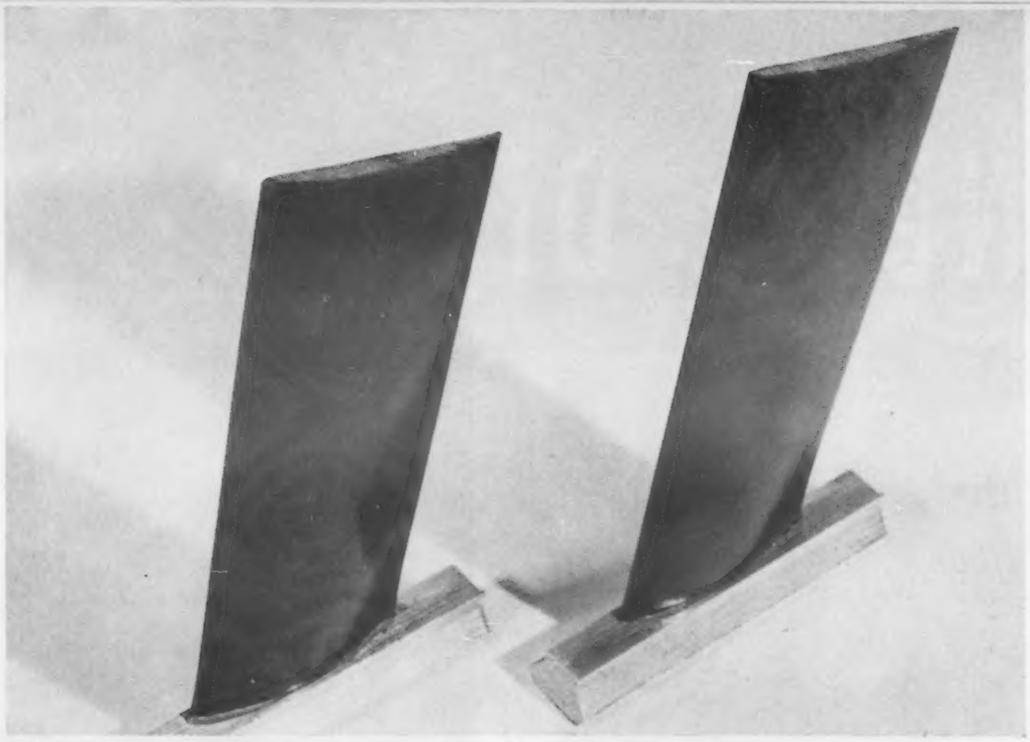
The 8000-ton press was designed to meet the need for an intermediate size unit between the existing 3000-ton and the now building 15,000-ton Alcoa units. Weighing 4 million pounds, the press was designed for ultra rigidity. It represents a departure from the conventional tie rod design usually used in such presses. The press is fabricated of 7 castings held together by shrink links over lugs and is approximately twice as heavy and rigid as other 8000-ton units. The rigidity of the press is expected to permit the unit to squeeze out unsymmetrical forgings without destroying press alignment or impairing tolerances. Its die bed is 11½ by 4½ ft.

In the East, Loewy Construction Co. reports installation of the 100-ft main columns of the 35,000-ton die forging press under construction for Wyman Gordon, North Grafton, Mass. The 100-ft column sections were among the largest forgings ever produced. As such, they have received wide attention in the metalworking industry throughout their fabrication and assembly.

Out West, Harvey Aluminum announces that it hopes to have its 12,000- and 8000-ton extrusion presses in production by midyear. The domestically built presses were designed to produce larger aircraft structural members. Using special extrusion techniques the presses will produce panel shapes in single sections up to 80 ft long and 60 in. wide.

***Main column** of 35,000-ton forging press is moved into position. More than half the length of the 100-ft. forged beam is in the pit. The press is one of two giants under construction at Wyman-Gordon, North Grafton, Mass.*





***Reinforced phenolic** compressor blades qualify for jet engine use. Material retains physical properties in the temperature range of 300 to 500 F.*
(Curtiss-Wright Corp.)

Plastics for Compressor Blades

Recent developments in plastics blades for jet engine compressors indicate that a glass-reinforced phenolic resin may be able to take over the air compressing job in some turbines.

Curtiss Wright Corp. revealed that a new high temperature phenolic resin reinforced with glass cloth maintains an ultimate strength of 40,000 to 50,000 psi at 500 F without evidence of creep. The blades have performed well as both stator vanes and as compressor blades, up to a temperature of 500 F. The material has about twice the strength to weight ratio of conventional metals, is corrosion resistant and has good resistance to damage and shock. Its strength at 500 F is superior to aluminum and magnesium, the company claims. Tooling costs for plastics blades are relatively low compared with metal, and the material is non-critical.

Attractive properties

Thompson Products, an active aircraft components manufacturer, reports that its research labs have been looking into plastics compressor blades for the last year and a half and have come up with some promising results. In a paper delivered to the SAE, A. T. Colwell, Thompson V. P., said, "Several properties of the plastic blade make it attractive. One consideration is that the fibrous glass reinforced plastics are non-critical materials. Also, the plastics blade has a relatively high damping capacity which keeps the stress low and the blade less susceptible to fatigue failure. Another advantageous characteristic is lightness, improving the accelerating characteristics of the engine. . . ." Colwell's report described the properties of the plastics blade as having "excellent dimensional uniformity and fine surface finishes." Blades showed no measurable creep in spin pit tests at 110% overspeed for 15 min.

Two main difficulties face plastics blade use, according to the SAE paper. The first is non-isotropic strength characteristics—the blade is not as strong in some directions as in others due to fiber orientation. The second difficulty is the lack of adequate inspection techniques to test for proper cure and bond. On the other hand, the Curtiss Wright technical report dismisses the unequal strength properties as unimportant. In fact, it approaches the property as an advantage, since maximum strength directions can be aligned to counteract the direction of maximum stress.

Future trend

Temperature limitations of the plastics blades are now 500 F, but both companies report that work in progress is promising to raise the temperature to 700 F. Neither would reveal how they expected to alter the material to hold up in such high temperature.

Plastics blades for turbines will probably not be used widely for engines of long lifetimes, or for supersonic missiles and aircraft, since the ram air temperature increases rapidly at supersonic speed. The most promising applications should be for target drones and low cost jet engines for turbine powered missiles with short lifetimes, such as the Bomark and Matador.

New Research Tools Announced

■ **Plastics Service Laboratory:** DuPont opened its new $3,000,000 sales service laboratory near Wilmington, Del. The completely equipped installation will concentrate on developing process and design techniques to improve plastics products. The lab will evaluate new materials in representative equipment under conditions found in general industry. The main objective of the laboratory is to reduce service problems and promote sound engineering in the application of plastics.

■ **Industrial Reactor:** Details of the first private industry owned and operated nuclear reactor for research use were revealed by American Machine and Foundry Co. The "swimming pool" type of reactor will develop 100 to 1000 kw and provide radiation densities in the megacurie range. The core structure and fuel assembly parts will be made of aluminum, the most satisfactory metal from a standpoint of corrosion resistance, cost, and low neutron cross section.

Copper Prices Hiked Exports Limited

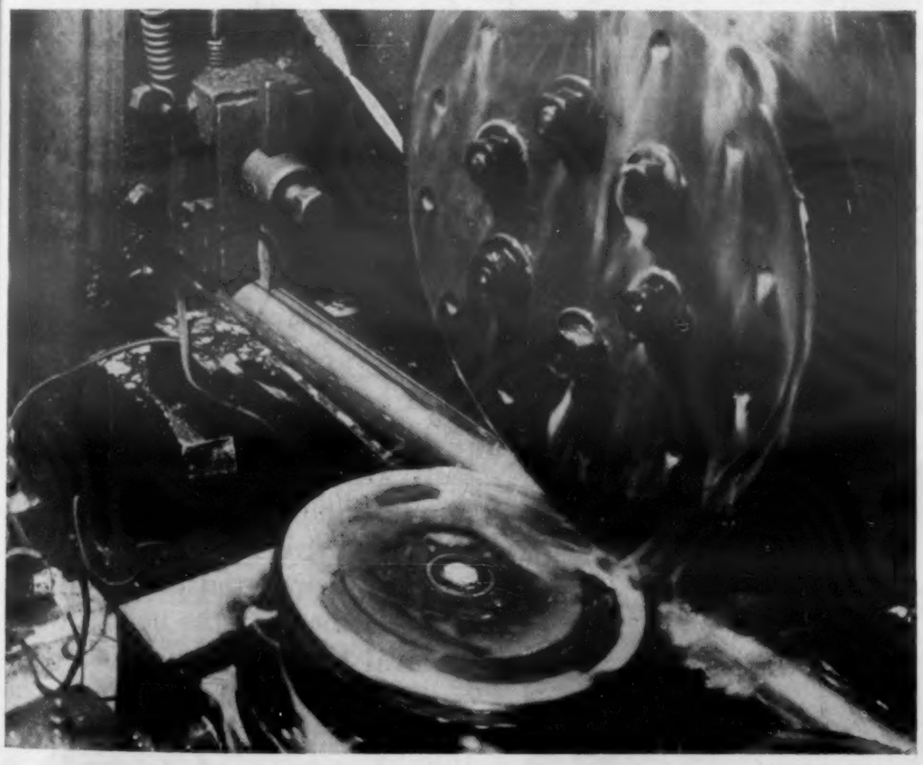
Europe's economic vitality, plus ikes in copper producing as, have resulted in an imbal- ce in the copper supply that s sent prices soaring on the ndon market. In February, S. copper producers reluctant- raised prices 3¢ per pound, the government limited all orts of domestically refined metal. Spot copper prices in ndon reached 44¼¢ per pound, higher than U.S. prices after 3¢ increase to 33¢ per pound. ports of copper of foreign gin were left uncontrolled by government to insure a ady supply to domestic refin- ies.

The high foreign prices for ap attracted a large amount the metal to export channels, putting a squeeze on custom smelters in the U.S. who depend exclusively on scrap. The result was, custom smelters could not compete with the larger primary copper producers. Here, scrap prices have been unstable, ranging from 30½¢ to 28½¢ a pound, representing a price range on the refined product from 33¢ to more than 35¢.

The price increase on refined copper was implemented very reluctantly by copper refiners, as they fear that any signs of higher prices or supply interruptions will drive their customers toward the booming aluminum industry. The recent price increase of 1¢ per pound for refined aluminum does not represent as much of a percentage increase as the copper price rise. Then too, the constantly increasing aluminum capacity of this country and Canada provides a stable source of supply for the light metal that is not likely to be affected by the vagaries of foreign markets.

The current copper shortage is described by industry spokesmen as a temporary, short-term squeeze that will disappear with the settlement of the latest strikes in Rhodesia. "There is plenty of copper", maintains the Copper and Brass Research Association. Right now, there are many in the industry who would like to see more copper coming their way.

While it is true that the long range copper picture is favorable and that there is no doubt there is plenty of copper to be had for many years to come, such short range scarcity and price fluctuations can drive fabricators away from the metal. Once tooled for another material, it is likely to take a considerable amount of selling to bring customers back.



Now Rolling. *The expanded facilities of Jones and Laughlin Steel Corp.'s Electricweld Tube Div. are now in operation. The mill operations are integrated from sheet stock to finished, painted tubing. Here, under cooled electrodes, the edges of the tubing are seam welded and the weld bead removed in a single operation.*

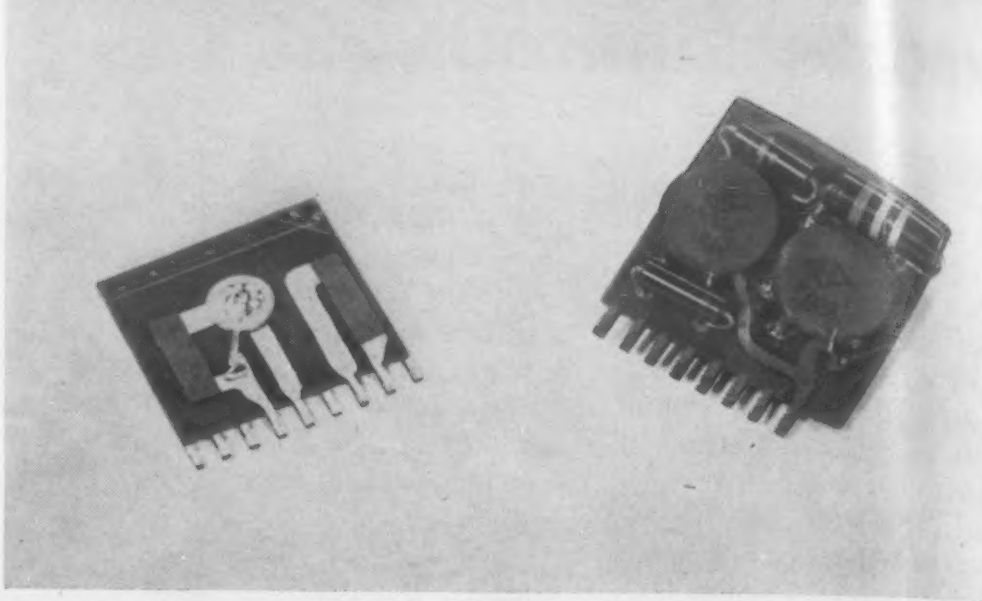
Zinc too?

London prices for zinc, above the New York price of 12¢, have caused talk of a price rise. Zinc of die casting grades is growing harder to find, probably due to booming automotive production. However, production of prime western zinc of the grade used for galvanizing is running well ahead of production. Government buying for stockpile is keeping inventories under control.

Although "competition" between aluminum and zinc for die casting is hotly denied by industry associations, it is not difficult to find major consumers of die castings who have continued to specify aluminum after the last zinc shortage even though they have paid a slight premium in production costs. Zinc producers, therefore, are exerting all possible efforts to prevent a rise in the price of die casting quality metal.

(More News Digest on page 14)

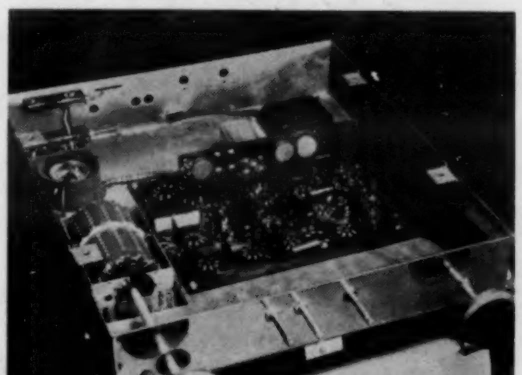
News Digest



***Printed circuitry** on left has printed resistors and capacitor elements. Equivalent circuit utilizing printed wiring and standard components is at right.* (Sanders Associates, Inc.)

Interest Grows in Printed Circuits

It has been said that if you want to fill a hall with engineers and businessmen, give a speech on automation, nuclear energy, or titanium. You can add printed circuits to that list, judging from the response to the Radio Electronics and Television Manufacturers' Symposium on Printed Circuits. The symposium held a standing-room-only audience of engineers from morning until almost midnight for two days running at The University of Pennsylvania's 800-seat University Museum Auditorium.



***Uncluttered appearance** of television chassis utilizing printed circuitry shows improvement over usual rats nest of wiring.* (Sanders Associates Inc.)

Judging from the status reports, new developments, work in progress, and above all the enthusiasm of the development engineers, the days of conventional point-to-point wiring techniques are numbered. Printed, etched, punched, embossed, painted, and metal powder circuitry has arrived—every technique is now in use commercially. Most five tube radio production is on printed circuits or is planned to be in the near future; several television manufacturers are "printing" large proportions of the complex circuitry in their sets, and it is safe to say there is no longer a single electronics manufacturer who has not made some plans to convert to a type of printed circuitry.

Actually, printed circuitry is somewhat of a misnomer, but it

(Continued on page 226)

DESIGNING WITH ALUMINUM

This is one of a series of information sheets which discuss the properties of aluminum and its alloys with relation to design. Extra or missing copies of the series will be supplied on request. Address: Advertising Department, Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

NO. 10

ALUMINUM SOLDERING

ALUMINUM has been considered to be a difficult metal to solder, but this is not true today. Aluminum can be readily soldered by using the commercially available materials and any of the soldering procedures commonly used with other metals.

Soldering Aluminum

Aluminum can be satisfactorily soldered for many applications by using a soldering iron, torch or furnace, or by employing dip or resistance soldering procedures. The surface oxide film can be readily removed by abrasion, ultrasonics or by using either a reaction or organic flux. The solder usually is an alloy of zinc containing one or more of the elements aluminum, cadmium, copper, silver, tin or lead. Aluminum soldered joints exhibit excellent mechanical properties and their corrosion resistance is determined by the composition of the solder. In general, the high zinc content solders develop the best corrosion resistance; soldered aluminum systems made with these solder alloys are still very serviceable after 7 years' outdoor exposure to an industrial atmosphere.

Parent Alloy

The solderability of aluminum alloys varies considerably with the amount of alloying constituents present. All aluminum alloys can be soldered by the employment of either abrasion or ultrasonic soldering techniques. However, if a flux is employed to remove the oxide film, the choice of aluminum alloys is restricted to those containing less than 4% silicon or 3% magnesium. For this reason, the alloys most commonly soldered are EC, 1100 (2S), 3003 (3S), 5005 (K155), 5050 (50S), 6061 (61S) and Kaiser Aluminum Utility Sheet.

Soldering Fluxes

There are two general types of aluminum soldering fluxes commercially available. The first type, called a reaction flux, relies on the reaction of a metal halide, such as zinc chloride or tin chloride, to remove the oxide film. This type of flux is generally preferred for soldering alloys containing magnesium or for soldering at temperatures of 650°F or higher. Reaction type fluxes are readily used in most soldering operations. However, the flux residue is capable of accelerating corrosion and it should be removed by thorough washing after the soldering operation is complete.

The second type of flux widely marketed is a chloride-free organic flux. This flux is normally useful only for low temperature soldering operations. The flux residue does not materially accelerate corrosion. Hence, organic fluxes have been used successfully in some commercial applications where the removal of flux residue is impracticable.

Fig. 1. This photograph shows an aluminum cable being soldered by immersion in a bath of molten solder. Using fluxes developed by Kaiser Aluminum, it is as easily dip soldered as the most soluble metals.

TABLE I Typical Compositions of Solders Commonly Used to Solder Aluminum

Alloy	Solder	% Sn	% Zn	% Pb	% Cd	% Al	% Cu	Melting Temperature*	Corrosion Resistance
1	Zinc Base		96.2			3.8		750	Best obtainable
2			94			4	2	740	Best obtainable
3			81.6	3	.4	10	5	750	Good
4	Tin Containing	28.2	70.9	.6			.3	710	Suitable for most indoor and some outdoor applications
5		64.9	35.1					615	"
6		50	15	.5	31.5	3		570	"
7	Lead Containing	40.6	21	37.7			.7	680	Must be protected outdoors but suitable for many indoor applications
8		31.7	9	51	8		.3	485	"
9		50	21.5	28.5				640	"

*Temperature at which the solder is completely liquid.

Alloys 1, 2 and 3 are widely used as abrasion type solders and are best applied using a gas torch. In addition, they can be used with reaction type fluxes and the commonly used sources of heat.

Alloys 4, 5 and 6 are general purpose alloys and are usually used with reaction type fluxes although they can be used with the organic types of fluxes if care is taken to avoid overheating. Torch, furnace and dip soldering procedures are generally used with these alloys.

Alloys 7, 8 and 9 are frequently used with the organic type of flux in low temperature soldering operations. These solders can be used with any of the common sources of heat, including the soldering iron.

Solders

The commercial solders can be classified into three general groups. The first group consists of alloys of zinc containing 3 to 10% aluminum and small amounts of other metals such as copper, silver and iron. This group of solders form the most corrosion resistant soldered assemblies, but they require soldering temperatures of 750°F to 800°F. The mechanical strength of joints made with the high zinc solder is excellent.

The second group of solders contain zinc and tin with small additions of copper, lead, cadmium or silver. They require soldering temperatures of 650°F to 750°F. These solders are general purpose materials and are extensively used by industry for those applications requiring a fairly simple soldering operation but where some sacrifice in corrosion resistance is permissible. The mechanical strength of

PLEASE TURN TO NEXT PAGE ➡

joints made with these solders is satisfactory for most applications; the shear strength will range from approximately 8,000 to 15,000 psi (pounds per square inch) of soldered area.

The third group of solders contain tin and zinc with major additions of lead and/or cadmium. These solders are characterized by low melting temperatures, which in turn permit low soldering temperatures of 450°F to 650°F. The shear strength of the soldered joints approaches that of soft soldered joints made in copper, i.e. about 7,000 psi. These solders produce joints having the lowest corrosion resistance but they are the easiest to use in a soldering operation.

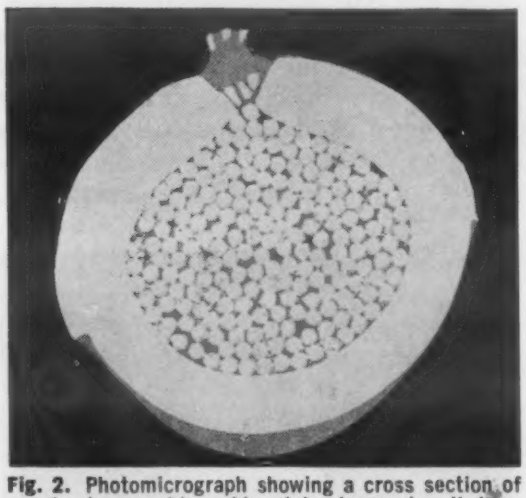


Fig. 2. Photomicrograph showing a cross section of an aluminum cable soldered by immersing it in a molten bath of 70% Zn 30% Sn solder using a liquid flux developed by Kaiser Aluminum. 5X.

Soldering Procedure

The fundamental operations involved in soldering are simple. The surface oxide film is removed and molten solder flowed over the clean surface to form a bond with the parent metal.

The first step in a soldering operation is the removal of the extraneous dirt and grease present on the surface. The commonly soldered aluminum alloys can be easily cleaned with organic solvents such as alcohol, carbon tetrachloride, etc. If the surface is badly weathered it should be wire brushed. The clean metal can then be soldered using either manual or mechanized soldering procedures commonly used for soldering other metals. The actual choice of solder, fluxes and soldering procedure will depend upon the specific joining problem at hand.

For manual soldering operations, gas torches, resistance tongs, or a molten bath of solder are commonly used as heat sources. Gas or electrically heated soldering irons find limited use for soldering thin aluminum assemblies or relatively small articles. A flux is generally used to remove the oxide film when using any of the heat sources mentioned. The solder can be either manually fed into the joint by using a rod of solder or it can be preplaced in the joint in the form of shims, rings, washers, etc. Ultrasonic vibrations have recently been introduced as a means of removing the oxide film on aluminum. Such vibrations currently have some limited use when dip soldering in a bath of solder. Furthermore, specially constructed ultrasonic soldering irons are being used fairly successfully. When soldering with a torch or ordinary soldering iron, it is also possible to use abrasion to remove the oxide film. This can be done by heating the aluminum with a torch or iron to the soldering temperature, melting a small amount of solder on the surface, and then removing the oxide film by abrading it with steel wool or a wire brush. Alternatively, a specially alloyed solder marketed as abrasion or friction solder may be rubbed directly on the surfaces to be soldered. If this is done, the oxide film is removed and the aluminum is coated with solder in one operation.

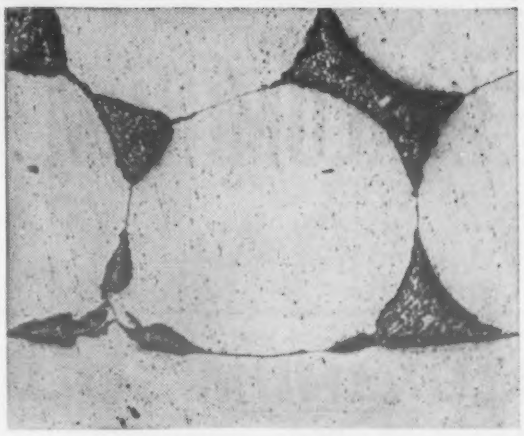


Fig. 3. This photomicrograph at 100X shows an enlarged section of the cable shown in Fig. 2. The solder has filled the interstices of the cable and joined the individual strands to each other to provide an electrical joint of minimum resistance.

In mechanized soldering operations the heat sources are usually multiburner torches, resistance tongs, a molten solder bath, electric resistance furnaces or electrical induction. A flux is usually used to remove the oxide in mechanized operations. The solder is preplaced in the joint using the common forms of preplaceable material, such as shims, washers, etc. Another effective method is to "pre-tin" at least one of the surfaces to be soldered to produce a coating of solder on its surface. This solder coating will melt when heated and it furnishes the solder necessary to fill the joint. Recently, some use has been made of ultrasonic vibrations applied directly to the dip soldering bath for removing the oxide film. In general, mechanized soldering operations should be completed in the shortest time possible to minimize warpage. The maximum speed attainable is determined by equipment limitations, although soldered aluminum joints have been made at speeds of over 200 feet per minute.

Corrosion Resistance

Soldered aluminum assemblies corrode because of the galvanic cell which results from the difference in electrode potential between the aluminum and the solder. These galvanic cells can be likened to small batteries in which the aluminum is the anode, the solder is the cathode, and the corrosive medium is the electrolyte. The current flowing in such a simple cell will be determined by the potential difference between the anode and cathode and the electrical resistance of the cell. If this analogy is correct, those metals having electrode potentials close to that of aluminum would make the most corrosion resistant soldered assemblies. On the other hand, those having the greatest potential difference would make the least corrosion resistant assemblies. In addition, we would expect the corrosion rate to be greatest in electrolytes or corrosion media which are good conductors of electric current. Conversely, corrosion would be the slowest in those which are poor conductors of electricity. In general we find this is true. The electrode potential of zinc is close to that of aluminum, and solders containing high percentages of zinc provide the most corrosion resistant soldered joints. Conversely, both lead and tin have potentials that are more widely separated from aluminum; hence, they provide a system having poor corrosion resistance. Therefore, the tin-lead solders commonly used with other metals are not suitable for soldering aluminum unless the assembly is protected from corrosive environments. In addition, we find that the corrosion rate is greatest in good electrolytes, such as salt solution, and is least in a poor conductor, such as pure water. Corrosion stops entirely when the assembly is exposed to dry air, under which condition no electrolyte is present.

More detailed assistance with design, alloy selection and fabrication procedures are obtainable through the Kaiser Aluminum sales office listed in your telephone directory, or through one of our many distributors. Kaiser Aluminum & Chemical Sales, Inc. *General Sales Office:* Palmolive Bldg., Chicago 11, Ill.; *Executive Office:* Kaiser Bldg., Oakland 12, California.

For more information, turn to Reader Service Card, Circle No. 441

tion and advantages of Wheelabrator blast cleaning and metal finishing. (18)

Steel Tubing. Avon Tube Div., 8 pp, illus. Gives fabrication and application data for thin-walled steel tubing. (19)

X-ray Equipment. Balteau Electric Corp., 6 pp, illus. Light weight x-ray unit with high power and penetration range. (20)

Cemented Carbide Tools and Blanks. Carboloy Dept., General Electric Co., 24 pp, illus, Brief-A-Log GT-285. Revised catalogue gives latest price changes and specifications on standard cemented carbide tools and blanks. (21)

Refractories. Carborundum Co., 24 pp, illus. Describes group of refractories having exceptional hardness, strength and heat resistance. (22)

Corrosion Control. Carpenter Steel Co., 28 pp, illus. Contains corrosion resistance tables, charts, and test results for stainless tubing and pipe. (23)

Phosnic Bronze. Chase Brass & Copper Co. Bronze alloy for jobs requiring high-strength metal with good conductivity. (24)

Metal Stampings. Crosby Co., 40 pp, illus. Describes company's range of facilities for metal stamping. (25)

Spray Painting Equipment. DeVilbiss Co., 64 pp, illus. Comprehensive treatment of equipment used in spray painting from operation to maintenance. (26)

Cork. Dodge Cork Co., Inc., 4 pp, illus, No. S-55. Physical properties, specifications and applications of natural cork and cork compositions. (27)

Rings. Dresser Mfg. Div., 4 pp, illus. Heavy industrial equipment fabrication from welded rings. (28)

Polyester Film. E. I. du Pont de Nemours & Co., Inc., Film Dept., 22 pp, illus. Discussion of range of applications of Mylar. (29)

Phenolic Resins. Durez Plastics & Chemicals, Inc., 6 pp, illus. Outlines uses of Durez resins, including compounded stocks, solvent-type adhesives, and use with latices. (30)

Muffles and Retorts. Electro-Alloys Div., American Brake Shoe Co., 6 pp, illus, No. T-239. Describes company's high heat-resistant muffles and retorts and outlines corrosion and abrasion resistance features. (31)

Electronic Machining. Electrosize, Inc., 4 pp, illus. Describes plant's custom service for precision machining carbides and hard metals by means of electrical discharges. (32)

Short Run Stamping. Federal Tool & Mfg. Co., 4 pp, illus. Describes company's facilities for short run stamping and phenolic die stamping. (33)

Cemented Carbides. Firth-Loach Metals, Inc., 20 pp, illus. Propane gas cutting tips for flame gouging, rivet blowing, flame hardening, heating, etc. (34)

O-Rings. Garlock Packing Co., 20 pp, No. AD-148. Gives design information, recommended pressures, and available materials for both "dynamic" and "static" applications. Listing of standard O-ring sizes in stock. (35)

Magnetic Cores. General Ceramics Corp., 4 pp. Graphs indicate magnetic properties of representative samples of company's magnetic cores. (36)

Industrial Laminates. General Electric Co., 8 pp. How to select particular grade of laminated plastic sheet applicable to specific design problems. Charts give description, properties and applications. (37)

Metallized Plastic Sheeting. Gomar Mfg. Co., Inc., 3 pp. Describes vacuum forming process and applications for metallized thermoplastic sheeting. (38)

Metal Stamping. Fred Goat Co., Inc., 18 pp, illus. Specification and application data for varieties of tube shields, clips, caps and rings. (39)

Polyvinyl Chloride Resin. Goodyear Tire & Rubber Co. Describes resin developed for extruded wire insulation materials. Properties and composition given. (40)

Perforated Materials. Harrington & King Perforating Co., 128 pp, illus, No. 62. Catalog of company's facilities for perforating metals and other sheet and plate materials. (41)

Heat Treating Ovens. Carl-Mayer Corp., 6 pp, illus, No. HT-53. Brief description of various types of heat treating furnaces and ovens. (42)

Screw Machine Parts. Kaiser Aluminum & Chemical Corp. Slide-rule calculator for estimating amount of aluminum stock needed for screw machine parts. (43)

Tension Control. Link Engineering Co., 4 pp, illus, No. LC3. Manual of automatically operated gage for indicating tension, weight and force of textiles, plastics, ball bearings, ropes, cables, etc. (44)

Clad Steels. Lukens Steel Co., 6 pp, illus. Price comparison of clad steels and solid high alloys. (45)

Micro-structural Section. Industrial Research Laboratory, Inc., 2 pp, illus. Describes cold-rolled miniature (⅜ in.) channel of high structural efficiency. (46)

Impact Extrusion. Magnesium Co. of America, 4 pp, illus. Lists types of impact extrusions and furnishes information on when this process should be used. (47)

Heat Treating. Metal Treating Institute, 16 pp, illus. Report of Institute's efforts to develop basic cost system which can be adapted to all types of heat treating operations. (48)

Metal Cleaning. Metalwash Machinery Corp., 12 pp, illus. Discusses types of cleaners, washing cycle, cleaning prior to plating or painting, etc. (49)

Rubber Linings. Metalweld, Inc., 8 pp, illus. Describes advantages and application of rubber lining to steel tanks, drums, pipes, valves, fittings and pumps. Includes data on physical properties and varieties of linings available. (50)

Induction Heating Control. Minneapolis-Honeywell Regulator Co., 16 pp, illus, No. HT-1. Discusses automatic temperature control for induction heating equipment. (51)

Fire-Resistant Hydraulic Fluid. Monsanto Chemical Co., 20 pp. Describes hydraulic fluid that reduces fire hazards and has operating qualities of petroleum fluid. (52)

Welding Rods. Mueller Brass Co., 4 pp, illus. Describes welding rods for oxy-acetylene welding of cast iron, malleable iron, steel and most copper-base alloys. (53)

Stainless Steel Tubing. A. B. Murray Co., Inc., 20 pp. Supplementary bulletin lists plant's complete stock of stainless tubing. (54)

Printed Circuits. National Vulcanized Fibre Co., 12 pp, illus. Discusses methods of producing printed circuits. Detailed specifications on grades and properties of copper-clad phenolic laminated plastic. (55)

Brass Powder Parts. New Jersey Zinc Co., 4 pp, illus. Describes applications of brass powder parts in self-developing cameras, rotors, drive bars. (56)

Industrial Tape. Polyken Products, 44 pp. Gives industrial uses for tape such as bundling, tube sealing, thread protection and edging. (57)

Seamless Mechanical Tubing. Pittsburgh Steel Co., 198 pp, illus. Applications, cost analysis, production techniques, inspection and testing methods, tolerances, chemical composition, physical properties, machining techniques, reference tables for full range of seamless mechanical tubing. (58)

Aluminum Extrusions. Precision Extrusions, 96 pp, illus. Catalog of available alloys and sections. (59)

Rust Prevention. Rust-Oleum Corp., 24 pp, illus, No. 254. Describes "Rust-Oleum", a rust-preventive coating, with instructions for surface preparation and application. (60)

Machining Alloy Steel. Joseph T. Ryerson & Son, 8 pp, illus, No. 14-5. Describes leaded alloy steel for fast machining. (61)

Aluminum Mill Products. Reynolds Metals Co., 16 pp, illus. Contains wrought aluminum selection guide outlining general properties of various aluminum mill products, and lists their applications. A casting alloy selection guide is also included. (62)

Precision Plating. Standard Pressed Steel Co., 32 pp, illus. Describes company's plating facilities and discusses some precautions to be taken to insure close tolerances. (63)

Perforated Metals. Standard Stamping & Perforating Co., 114 pp, illus. Catalog of perforated metal samples and information on manufacturing processes and applications. Write directly to Standard Stamping & Perforating Co., 3131 W. 49th Pl., Chicago 32, Ill.

Heat Treating Equipment. Stanwood Corp., 4 pp. Brief description of types of heat treating equipment with suggested applications. (64)

Quenching Oil. Sun Oil Co., 2 pp, No. 29. Describes oil of high thermal stability and high boiling range. For quenching systems requiring a high flash-point and for bright quenching from controlled atmosphere furnaces. (65)

Manufacturers' Literature

Rubber. Sun Rubber Co., 22 pp, illus. Describes plant's facilities for processing, curing and finishing rubber products. (66)

Automatic Carbon Control in Heat Treating. Surface Combustion Corp., 4 pp, illus, No. SC-168. How to control carbon potential of furnace atmosphere for case carburizing, homogenous carburizing, carbon restoration and clean hardening. (67)

Electroplated Palladium and Platinum. Technic Inc. Data sheet describes physical and electrical properties for both metals. Includes corrosion data, specifications, and thickness requirements. (68)

Stainless and High Alloy Tubing. Trent Tube Co., 48 pp, illus. Classifies types of tubing, giving typical applications, physical, chemical and electrical properties for each. Information on welding, bending and installation techniques. (69)

Flexible Plastic Tubing. U. S. Stoneware Co., 28 pp, illus. Gives properties and uses of extruded vinyl plastic tubing available in semi-rigid or flexible sheets, tubing or solid cord. (70)

Super Alloys. Universal-Cyclops Steel Corp., 22 pp, illus. Describes high strength heat and corrosion resistant alloy and its applications. Tables and charts give properties and forms available. (71)

Aluminum Extrusions. Valley Metal Products Co., 4 pp, No. 015. Standard forms of aluminum extrusions. (72)

Phosphating Solvent. Whitfield Chemical Co., 8 pp, illus. Describes non-toxic, non-inflammable liquid phosphating solvent for metal cleaning. (73)

Forgings. J. H. Williams & Co., 20 pp, illus. Describes company's facilities for all phases of forging, including cleaning and finishing. (74)

Other Available Literature

Irons and Steels • Parts • Forms

Wire Parts, Small Metal Stampings. Art Wire & Stamping Co., 4 pp, ill. Profusely illustrates a variety of wire parts and small metal stampings produced in both ferrous and nonferrous metals. (75)

Precision Castings. Austenal Laboratories, Inc., Microcast Div., 16 pp, ill. Describes Microcast Process for manufacture of precision cast parts, including specifications and explanation. (76)

Low-Alloy Steel. Bethlehem Steel Co., 66 pp, ill, No. 353. Properties and features of Mayari*R steel for use in applications requiring high strength and good wear and corrosion resistance. (77)

Welded Steel Tubing. Brainard Steel Co., Tubing Div., 8 pp, ill. Shows facilities for manufacturing welded steel tubing, its applications, fabrications, specifications. (78)

Wire Cloth. The Cambridge Wire Cloth Co., 84 pp, ill. Illustrates the many different types of wire cloth, their typical applications and specifications. (79)

Cast Iron. Carondelet Foundry Co., 4 pp, ill. Discusses a variety of modern cast irons controlled and alloyed for industrial requirements. (80)

Cast Alloys. Cooper Alloy Foundry Co., 11 pp. Reference sheets covering major stainless alloys. Includes chemical composition, mechanical and physical properties, resistance to major corrosive solutions, machinability, heat treatment and weldability. (81)

Stainless Steel. Crucible Steel Co. of America. Slide rule type reference chart for physical properties, corrosion resistance, resistance to scaling, machinability, weldability, hardenability of 27 different stainless steels. (82)

Stainless Steel Tubing and Pipe. Damascus Tube Co., 8 pp, ill. Profusely illustrates the manufacturing process of stainless steel tubing and pipe offered by Damascus. (234)

Gray Iron Castings. Dostal Foundry Machine Co. Permanent mold gray iron casting facilities. (83)

Iron Powder. Easton Metal Powder Co., Inc., 5 pp, ill. Specifications for designing for Ferroflame "A" iron powder. (84)

Investment Castings. Engineered Precision Casting Co., 8 pp, ill. Complete data on EpCo precision investment castings of stainless steel, alloy tool steel, beryllium-copper and most metals that can be melted. (85)

Gray Iron. Gray Iron Founders' Society, Inc., Data Sheet and 12 pp booklet. Data sheet summarizes gray iron specifications. Booklet contains articles on how and when to use gray iron, and its adaptability for casting. (86)

Stampings. H.P.L. Mfg. Co., 4 pp, ill, No. 718. Facilities for production of stampings in small lots. (87)

Hardness Conversion Tables for Steel. International Nickel Co., Inc. A celluloid card, wallet size, gives approximate relationship between Brinell, DPH (Vickers), Rockwell and Shore Scleroscope hardness values and corresponding tensile strengths of steel. (88)

Heat Treated Steel. Jones & Laughlin Steel Corp., 9 pp, ill. Describes method of heat treating cold finished steel bars, utilizing electric induction heating and quenching equipment. (89)

Lead-Bearing Steel Bars. La Salle Steel Co., 8 pp, ill, No. 8. Properties and applications of a complete line of La-Led free-machining, lead-bearing steel bars. (90)

Malleable Castings. The Malleable Founders Society, 8 pp, ill, No. 47. Analysis of good practice in tolerances and specifications of malleable castings. (91)

Threaded Stampings. Mohawk Mfg. Co., 2 pp, No. 851. Illustrates variety of products produced by Mohawk's stamping processes, guaranteeing uniform threaded parts with uniformly threaded holes. (92)

Precision Investment Castings. National Precision Casting Corp., 4 pp, ill. Pictures various steps in the precision investment casting process offered by this company that saves time and money. (93)

Seamless Steel Tubing. National Tube Div., U. S. Steel Co. Explains time- and cost-cutting fabricating applications of this company's Shelby seamless tubing. (94)

Tubing. Ohio Seamless Tube Div., Copperweld Steel Co., 8 pp, ill. Specifications and applications of a variety of Ostuco seamless and welded tubing. (95)

Iron Powder Parts. Pow Met Industries, Inc., 4 pp, ill. High density, heavy duty iron powder parts. (96)

Metal Containers. Pressed Steel Tank Co., 16 pp, ill. Tells how many industries have been helped in quality production at low cost by use of Hackney Metal containers and deep drawn component parts. (97)

Roll Formed Shapes. Roll Formed Products, 24 pp, ill, No. 1053. Shows production procedures and advancements in roll forming shapes from ferrous and nonferrous metals. (98)

Steel Hydraulic Tubing. Summerill Tubing Co., Div. Columbia Steel and Shafting Co., 8 pp, ill. Discusses tubing requirements, specifications for hydraulic applications, and advantages of steel seamless tubing. (99)

Spun Metal Parts. Roland Teiner Co., Inc., ill, No. 51D. Brochure describes this company's facilities for spinning practically any metal or gage required. (100)

Graphitic Steel. The Timken Roller Bearing Co., Steel & Tube Div. Data on properties and applications of graphitic steels. (101)

Precision Casting. Thompson Products, Inc., Metallurgical Products Div., 8 pp, ill, No. MP-53-1. Discusses the Intricast process of precision casting any castable metal or alloy. (102)

Small Precision Metal Parts. Torrington Co., 4 pp, ill. Illustrates the various small precision metal parts custom-made by the Specialties Div. of Torrington. (103)

Alloy Steel Castings. Unitcast Corp., 2 pp. Specifications, characteristics and uses of T-loy 42, alloy steel castings. (104)

High Strength Steel. U. S. Steel Corp., 46 pp, ill, No. ADVL-317-54. Properties and fabrication data for Carilloy T-1, new high strength weldable steel with exceptional toughness. (105)

Pipe and Tubing. The Wallingford Steel Co., 8 pp, ill. Stainless, carbon and alloy steel tubing for ornamental, mechanical, pressure, sanitary and aircraft use in size range from ¼-in. to 3-in. O.D. (106)

Manufacturers' Literature

Stainless Steel Castings. Waukesha Foundry Co., 4 pp, ill, No. WF-6. Discusses the facilities of this company for producing corrosion resistant high alloy, heat resistant stainless steel castings. (107)

Magnetic Alloys. Westinghouse Electric Corp., 8 pp, No. TD 52-100. Complete data on a variety of magnetic alloys produced by this company includes applications and 15 core loss and magnetization curves. (108)

Nonferrous Metals • Parts • Forms

Bronze Bushings, Bearings, Etc. American Crucible Products Co., 12 pp, ill. Technical data on a variety of Promet bronze bushings, bearings, bar stock and babbitt metal available in a series of standard formulas. (110)

Prefinished Metal Sheet. American Nickeloid Co., 24 pp, ill. Properties and fabrication information on prefinished metal sheet. Includes examples and case histories of uses. (111)

Cast Aluminum. American Smelting & Refining Co., 20 pp, ill, No. 165. "Practical Help in the Casting of Aluminum Alloys". Deals with the effects of moisture, shrinkage, dross, pouring temperature and test bars. (112)

Precision Investment Castings. Arwood Precision Casting Corp., 16 pp, ill. Informative article on precision investment castings. Includes table of ferrous and nonferrous alloys recommended as most adaptable for this process. (113)

Vacuum Die Casting. Aurora Metal Co., 8 pp, ill. Describes process for aluminum bronze and silicon bronze. Applications, physical and chemical specifications. (114)

Small Tubular Parts. The Bead Chain Mfg. Co. Describes Multi-Swage Process for economically custom producing small mechanical parts up to ¼-in. dia. and 2-in. length. (115)

Magnesium. Brooks & Perkins, Inc., 8 pp, ill. Describes facilities and services of this company for fabricating magnesium. (116)

Custom and Standard High Alloys. Cannon Muskegon Corp., 4 pp, ill. Ferrous and nonferrous alloys for castings, extrusions and forgings. For remelt or direct use. (117)

Punch and Die Setting Alloy. Cerro de Pasco Corp., 20 pp, ill, No. A15. Properties and description of use of Cerromatrix for setting various types of dies and punches. Shows advantages over solid dies. (118)

Titanium, Aluminum Alloy Steel Forgings. Consolidated Industries Inc., 4 pp, ill. Profusely illustrates a complete line of precision forgings made of these materials. (119)

Aluminum Finishing. Diversey Corp., file folder. Aluminum cleaning compounds, scaling, welding, anodizing, etching and painting. (109)

Zirconium. Firth Sterling, 4 pp. Properties of pure zirconium metal with strengths of various forms and comparative corrosion resistance. (120)

Metal Stampings. Geometric Stamping Co., 4 pp, ill. Suggestions for cost savings through conversion from castings to stampings. (121)

Investment Castings. Gray-Syracuse, Inc., 4 pp, ill. Parts of precision cast brass bronze, beryllium copper and steel. (122)

Zinc Alloy Die Castings. Gries Reproducer Corp., 4 pp, ill. Stock list of company's small die castings. (123)

Copper and Brass Tubing. H & H Tube & Mfg. Co. Describes a complete line of seamless braze and lock seam copper and brass tubing. (124)

Precision Manufacturing Service. Hamilton Watch Co., 16 pp, ill. Special alloy casting, rolling, drawing to fine specifications. (125)

Aluminum Extrusions. Harvey Aluminum Div., Harvey Machine Co., 8 pp, ill. Properties, characteristics and application of a variety of aluminum extrusions produced by this company. (126)

Nickel-Base Alloys. Haynes Stellite Div., Union Carbide and Carbon Corp., 40 pp. Properties, specifications and uses of Hastelloy corrosion resistant grades. (127)

Aluminum Alloy Selector. Howard Foundry Co. A slide rule type selector for permanent mold cast aluminum alloys and sand cast aluminum alloys. Write on company letterhead direct to Howard Foundry Co., 1700 N. Kostner Ave., Chicago 39, Ill.

Aluminum Impact Forgings. Hunter Douglas Corp., 4 pp, ill. Design suggestions for impact forgings and impact extrusions of aluminum alloy parts. (128)

Laminated Metals. Improved Seamless Wire Co., Inc., 6 pp, ill. Describes the importance and applications of laminated metals to modern industry. (129)

Bronze Bars. Johnson Bronze Co., 4 pp, ill. Completely machined 13-in. bars for bearings, bushings, thrust plates and washers. Other applications and machining data listed. (130)

Magnesium. Magline Inc., 8 pp, ill. Facilities for fabricating magnesium and producing sand castings. (131)

Tin. The Malayan Tin Bureau. "Tin News," a monthly publication of the Malayan Tin Bureau, reviews market situation, tin uses and political developments affecting the supply of tin. (132)

Castings. Meehanite Metal Corp. Physical specification chart for engineering design in the form of a calculating wheel. Characteristics of general engineering, heat-resisting, corrosion-resisting and wear-resisting metals. (133)

Precision Castings. Ohio Precision Castings Inc., 12 pp, ill. Numerous examples of industrial applications of this company's brass, bronze, aluminum and beryllium-copper plaster mold castings. (235)

Die Castings. Paramount Die Castings Co., 4 pp, ill. Describes facilities and services and shows representative aluminum, magnesium and zinc castings. (134)

To obtain literature appearing on these pages, please refer to easy-to-use reply card on pages 69 and 70

Die Castings. Precision Castings Co., Inc., 24 pp, ill. Describes company's integrated facilities for quantity production of aluminum, magnesium and zinc die castings. (135)

Condenser Tubes. Revere Copper and Brass Inc., 28 pp, ill. Detailed discussion of ways to make condenser tubes last longer, what they are made of, and new developments in materials. (136)

Magnesium and Aluminum Castings. Rolle Mfg. Co., Inc., 16 pp, ill. Background history and current progress of magnesium and aluminum castings. Includes illustrated case histories and data on new magnesium-zirconium alloys. (137)

Strip and Sheet Brass. Scovil Mfg. Co., 4 pp, ill. Continuous-cast strip and sheet brasses and bronzes. (138)

Aluminum Bonded to Steel. Arthur Tickle Engineering Works, 8 pp, ill. Describes process for molecular bonding of aluminum to iron and steel, its applications and advantages. (139)

Screw Machine Products. Westfield Metal Products Co., Inc., 4 pp, ill. Describes facilities for the production of a variety of machines, nuts and screw machine products. (140)

Flanged and Dished Heads. Wickwire Spencer Steel Div., Colorado Fuel & Iron Corp., 130 pp, ill. Comprehensive information and engineering data on C F & I flanged and dished heads, flueholes, handholes, saddles, etc. (141)

Mechanical Tubing. Youngstown Sheet & Tube Co., 4 pp, ill. Features size and wall thickness of a complete line of Yoloy electric weld mechanical tubing. (142)

Spun Tubing. Wolverine Tube Div., 28 pp, ill. Advantages and numerous applications of this firm's nonferrous Spun End Tube Process. (143)

Nonmetallic Materials • Parts • Forms

Plastic Molding. Ackerman Plastic Molding Div., 4 pp, ill. Long run production of plastic parts by compression of plunger molding. (144)

Filter Mat. American Felt Co., 6 pp, ill. Technical data and sample of Dynel Windsor Felt, a new fiber-bonded filter mat for use in filter press or vacuum filter applications. (145)

Gasket Materials. Armstrong Cork Co., 24 pp, ill. Complete data on various cork and rubber gasket materials made to meet government specifications. (146)

Phenolic Resins. Borden Co., Chemical Div., 8 pp, ill. Durite phenolic molding compounds, bonding resins, basing resins, and impregnating resins. (147)

Plastics. Ciba Co., Inc., Plastics Div., 625 Greenwich St., New York 14, N. Y. Complete technical data on the physical properties and recommended procedures for the successful use of Araldite Resins for individual fabricating needs. Write direct to Ciba on company letterhead.

Fabricating Plastics. Continental Diamond Fibre Co., 64 pp, ill, price 50¢. Reference book contains suggestions on general rules to follow, tooling recommendations, and feeds and speeds. (148)

Manufacturers' Literature

Plastics. The Dow Chemical Co., 20 pp, ill. Products, applications and technical services outlined in this brochure on Dow's line of plastics which includes Styron, Ethocel, Saran and Vinyls. Includes charts of properties, case histories of applications and description of engineering services offered by the company. (149)

Industrial Textile Fibers. E. I. du Pont de Nemours & Co., Inc., Textile Fibers Dept., 20 pp. Consideration of synthetic fibers as industrial materials. Includes rayon, acetate, nylon, orlon, dacron, teflon fibers. (150)

Felt and Felt Products. Felters Co., 16 pp, ill. Includes properties, applications and specifications of felt as a design material and various felt products. (151)

Molding Compounds. Fiberite Corp., 1 p, No. 6. Lists phenolic, melamine and other resin-based molding compounds. (152)

Thermoplastic Resins. Firestone Plastics Co., Div. of Firestone Tire & Rubber Co., 20 pp, ill. Properties and use of Exon vinyl resins. Describes technical service facilities available. (153)

Setting Compound. Furane Plastics, Inc., 1 p, No. A-2-52. Data on Furane Resin X-2, in conjunction with activated silica, which forms a very fast setting compound. (155)

Rubber Mountings and Bushings. General Tire & Rubber Co., Industrial Products Div., 12 pp, ill, No. 701. Rubber-core mountings and bushings for vibration-isolation and oscillatory-motion bearings. (154)

Polystyrene Sheet. Gilman Bros. Co., 4 pp, ill. High impact polystyrene sheet for vacuum forming. Has five times the strength of general-purpose sheet. (156)

Hycar Rubber. B. F. Goodrich Chemical Co., 22 pp, ill. Complete analysis of properties and uses of Goodrich oil and solvent resistant rubber. (157)

Self-Lubricating Bushings. Graphite Metalizing Corp., 8 pp, ill, No. 108. Describes Graphalloy grades for bushings and electrical uses. Bearing design data included. (158)

Plastics. Heil Process Equipment Corp., 4 pp, ill, Vol 4, No. 1. Suggests applications for Rigidon, a glass-reinforced plastic; Rigidin, a rigid vinyl plastic; and Rigidene, a polyethylene plastic. (159)

Fluorocarbon Plastics. M. W. Kellogg Co., 16 pp, ill. Index of processors and converters, manufactured items and services connected with the production of Kel-F parts and forms. (160)

Foam Polystyrene. Koppers Co., Inc., 10 pp, No. C-4-200-T. Describes expandable polystyrene beads and polystyrene foam. Includes physical and chemical property listings, suggested applications, molding data and instructions for use of adhesives with the material. (161)

Glass. Libbey-Owens-Ford Glass Co., 8 pp, ill. Glass in product and engineering design. (162)

Refractory Porcelain. McDanel Refractory Porcelain Co., 36 pp, ill. Catalog of high temperature porcelain products with physical, mechanical and electrical properties. (163)

Glass Bonded Mica. Mycalex Corp. of America, 24 pp, ill. Design information for parts to be machined from glass bonded mica. (164)

Plastic Resins and Compounds. Naugatuck Chemical Div., 8 pp, ill. Vinyl, polyester and elastomeric resins and compounds, applications, properties and processing. (165)

Nonmetallic Material. Neff-Perkins Co., 8 pp, ill, No. GC-4-54. Describes materials, products and engineering services covering a broad range of nonmetallic materials for industry. (166)

Electrochemically Refined Materials. Norton Co. Lists complete line of electrochemically refined refractory materials for industry. (167)

Fiber Glass. Pittsburgh Plate Glass Co., 4 pp, ill. Lists advantages of using fine glass fiber mat for sound heat insulation application. (168)

Polyester Resins. Reichhold Chemicals, Inc. Brochure includes 11 technical bulletins of 2 to 6 pages each describing the Polylite line of liquid thermosetting polyester resins. The bulletins cover molding characteristics and physical properties of 10 resins of various heat and light resistant grades, suitable for use in glass fiber reinforced applications. (169)

Adhesives. Rohm & Haas Co., 10 pp, No 20R. Describes in detail Uformite 400, a high-solid, aqueous urea-formaldehyde resin adhesive especially designed for bulk shipment and storage. (170)

Gasket Sheeting. Rogers Corp., 4 pp, ill. Describes a line of asbestos-elastomer material. (171)

Plastics. Sillcocks-Miller Co., 4 pp, ill. Applications of plastics as an alternate to hard-to-get metals. (172)

Electronic Components. Stackpole Carbon Co., 42 pp, ill, No. RC-8. Catalog shows complete line of this company's electronic components. Includes helpful engineering data. (173)

Machining Laminated Plastics. Synthane Corp., 6 pp, ill. Recommended techniques for common machining operations on laminated plastics. Includes properties and design hints. (174)

Vulcanized Fiber and Laminated Plastics. Taylor Fiber Co., 4 pp. Basic properties of plastic laminates and vulcanized fibrous materials given in convenient tables. (175)

Pipe Fittings. Tennessee Eastman Co., 16 pp, ill, No. T-52-689. Detailed diagrams explain the fabrication of various fittings from extruded pipe lengths, using Tenite plastic. (176)

Molded and Extruded Rubber Parts. Tyer Rubber Co., 8 pp, ill, No. 1P52. Detailed information on various types of molded and extruded parts of natural and synthetic rubber. (177)

To obtain literature appearing on these pages, please refer to easy-to-use reply card on pages 68 and 69

Plastisol. United Chromium Inc., 4 pp, ill. Physical, chemical properties of Unichrome plastisol compounds used for coating, casting or molding. (178)

Thermoplastic. Colonial Plastics Mfg. Co., Industrial Div., 16 pp. Technical data on properties, available forms, fabrication and applications of Lucoflex, a rigid polyvinyl chloride. (179)

Laminated Plastics. Westinghouse Electric Corp., 50 pp. Catalog on industrial Micarta covering all grades and forms in which Micarta is supplied, and the chemical, mechanical and electrical properties of each. Machining data gives fabrication information. (180)

Finishes • Cleaning and Finishing

Chromate Conversion Coatings. Allied Research Products Inc., 4 pp, ill, No. 8. Complete data on the basic characteristics of Iridite chromate conversion coatings, and their functions on various metals. (181)

Zinc-Plate Bright Dip. The Chemical Corp. Information on Luster-On Utility-25 bright dip for zinc-plated surfaces. Highly resistant to corrosion. (182)

Spray Painting. Conforming Matrix Corp., 5 pp, ill. Gives description, uses, and advantages of this firm's spraying masks, mask washing machine, and spray painting equipment. (183)

Wet-Blasting. The Cro-Plate Co., Inc., 8 pp, ill. Equipment for two-speed wet-blasting for finishing metal parts. (184)

Black Oxide Finish. Du-Lite Chemical Corp. Information on Du-Lite finishes for any steel blackening problem. Also gives information on Du-Lite cleaner, strippers, burnishing compounds, etc. (185)

Barrel Finishing. Lord Chemical Corp., 32 pp, ill. Introductory bulletin describes various compounds for precision barrel finishing. (186)

Metal Cleaner. Mitchell-Bradford Chemical Co., 1 p. Description of Magiclene #2 cleaners and degreasers. (187)

Micropolishing. The Murray-Way Corp. Engineering specifications and auxiliary equipment needed for micropolishing. (188)

Metal Cleaner. Niagara Alkali Co. Pamphlet gives properties of Nialk Trichlorethylene, high quality metal-cleaning and degreasing agent. (189)

Phosphate Coatings. Pennsylvania Salt Mfg. Co., 5 pp, ill. Description of the Fosbond process of phosphate coatings for metal finishing. (190)

Industrial Brushes. Pittsburgh Plate Glass Co., Brush Div., Dept. W-4, 3221 Frederick Ave., Baltimore, Md. Case histories indicate economies available to users of Pittsburgh brushes. Request on company letterhead direct from this company.

Metal Surface Finishing. Roto-Finish Co., 6 pp, ill. Folder describes precision finishing process and various types of machines developed for diverse job requirements. (191)

Surface Coatings. Shell Chemical Corp., 32 pp, ill. Epon resins: physical prop-

erties, chemical properties, solubility and compatibility formulas, data and reference tables. (192)

Porous Chromium Coating. Van der Horst Corp. of America, 12 pp, ill. Describes an oil retaining, wear resistant chromium coating for bearing surfaces, cylinder walls and applications where hard wear and lubrication are factors. (193)

Heat Treating • Heating

Heat Treating. Ajax Electric Co., Inc. Pocket-sized slide chart for calculating heating time of steels. Write on company letterhead direct to Ajax Electric Co., Inc., Frankford at Delaware Ave., Philadelphia, Pa.

Roller Hearth Furnaces. Drever Co., 8 pp, ill, No. B-90. Profusely illustrates a variety of oil, gas or electrically heated, direct fired or radiant tube roller-hearth furnaces. Includes specifications. (194)

Heat Treating Furnaces. The Electric Furnace Co., 4 pp, ill. Shows various gas, oil and electric furnaces for annealing and heat treating requirements and lists applications. (195)

Reducing Atmosphere Generators. Gas Atmospheres, Inc., 4 pp, ill, No. R-352. Atmosphere generators for industrial applications such as bright hardening, annealing, gas carburizing and sintering. (196)

Furnaces. C. I. Hayes Inc., 44 pp, ill, No. 112. Complete data on a variety of furnaces for hardening, tempering, carbonitriding, forge heating, sintering, annealing and tool heat treating, as well as on atmosphere generators and ammonia dissociators. (197)

Heat Treating Furnaces. Hevi Duty Electric Co., 8 pp, ill, No. 653. Describes furnaces for annealing, stress relieving, nitriding, etc. (198)

Electric Heating Elements. Holcroft & Co., 4 pp, ill. Describes four types of electric heating elements and their mounting methods. Classifies heat treat furnaces according to stock handling method. (199)

Gas-Fired Vertical Radiant Tube Furnaces. Lindberg Engineering Co., 44 pp, ill, No. 241. Design and application features of Lindberg carbonitriding furnaces that can be used for carbonitriding as well as carburizing, annealing, carbon restoration. (200)

Tubular Furnaces. Marshall Products Co., 4 pp, ill. Discusses both the creep test and tensile test models of Marshall tubular furnaces, as well as control panels and radial brackets. Includes specifications. (201)

Electric Furnaces. Pereny Equipment Co., 3 pp, ill, No. 4A. Booklet tells advantages and illustrates typical group of furnaces and kilns and their uses. (202)

Induction Heating. The Ohio Crankshaft Co. Describes plant survey and possible applications to which induction heating might be put for greater production economy. (203)

Vacuum Furnaces. F. J. Stokes Machine Co., Inc., 8 pp, ill. Discusses effects of processing various metals and alloys in vacuum. Includes applications of vacuum furnaces in melting and casting new metals. (204)

Electric Radiant Panels. Edwin L. Wiegand & Co., 6 pp, ill, No. CS605. Folder includes a variety of applications of Chromalox electric radiant panels—compact, "packaged" for infra-red generators. (205)

Welding • Joining

Rubber-to-Metal Bonding. Acushnet Process Co., 8 pp, ill, No. 51-A. Supplement A to the Acushnet rubber data handbook gives more detailed information concerning the rubber-to-metal adhesion process. (206)

Silver Brazing. American Platinum Works, 48 pp, ill. Reference manual on silver brazing discusses low temperature brazing, brazing alloys, design considerations and other topics. (207)

Bronze Electrodes. Ampco Metal Inc., 24 pp, ill, No. W17. Describes complete line of products for use with metal-arc, tungsten-arc, carbon-arc, submerged-arc and inert-arc consumable electrode process. (208)

Silver Brazing Alloys. Handy & Harman, 24 pp, ill, No. 20. Information on Easy-Flo and Sil-Fos low temperature silver brazing alloys, and valuable data on brazing methods. (209)

Fasteners. H. M. Harper Co., 8 pp, ill, Vol. 19, No. 2. Various case histories of the applications of Harper's fasteners, emphasizing corrosion-resistant bolts. (210)

Electrodes and Holders. P. R. Mallory & Co., Inc., Welding Div., 2 pp, ill, No. 8-11. Advantages, design and application of 8-deg (4 deg per side) ⅝-dia spot welding electrodes and holders. (211)

Gold and Platinum Solders. The J. M. Ney Co., 1 p. Data sheet gives melting ranges and colors of this company's gold and platinum solders for electronic tube applications. (212)

Screws. Russell, Burdsall & Ward Bolt & Nut Co., 8 pp, ill. Presents principle of fastening, advantages and specifications of a complete line of Spin-Lock screws available in hex, pan, truss or flat heads. (213)

Welding Machines. Sciaky Bros., Inc., 5 pp, ill. Description of multiple gun electrical resistance welding machines. (214)

Cold Formed Fasteners. Townsend Co., 4 pp, ill, No. TL89. Discusses features, advantages and design requirements for fabricating cold headed parts and fasteners. (215)

Brazing Alloys. United Wire & Supply Co., 3 pp, ill. Wire brazing aluminum for low temperature brazing of various metals and alloys. (216)

Weldments. The Van Dorn Iron Works Co., 10 pp, ill. Shows this company's facilities for producing weldments and other parts in all sizes and examples of the type of work produced. (217)

Forming • Casting • Molding • Machining

Flame Hardening. The Cincinnati Milling Machine Co., 20 pp, ill, No. M-1624. Electronic control flame hardening machine for hardening parts in production quantities to conform to metallurgical standards previously impractical. (218)

Moly-Sulfide Lubricant. Climax Molybdenum Co., 40 pp. Detailed tables of applications of moly-sulfide lubricant in the manufacturing plant, the job shop and the field, indicating form used, and results of application. (219)

Cold Extrusion. Mullins Mfg. Corp., Kold-flo Div., 16 pp, ill. How low carbon steel parts are cold extruded and fabricated in one piece without machining. (220)

Screw Machine Parts. Ottawa Steel Products, Inc., 4 pp, ill. Manufacturing facilities for ground and hardened screw-machine products. (221)

Tube Mills. The Yoder Co., 65 pp, ill. Pros and cons of operating a tube mill, plus detailed information on the process. Also technical data on standard and other equipment. (222)

Inspection • Testing • Control

Universal Testing Machines. Baldwin-Lima-Hamilton Corp., 4 pp, ill, No. 4213. Describes two low-cost Baldwin-Tate-Emery universal testing machines of 20,000- and 60,000-lb capacity. (223)

Fine Grinders. Buehler Ltd., 4 pp, ill. Fine metallurgical grinding machines for the laboratory, hand grinders and abrasives. (224)

Radiography. General Electric Co., X-Ray Dept. A new house organ, "Radiation Digest," devoted to industrial x-ray applications and commercial irradiation techniques. Contains news of the field and feature articles. Published quarterly. (225)

Furnace Temperature Indicator. Claud S. Gordon Co., 2 pp, ill. Describes device which quickly indicates any deviation from desired furnace temperature. (226)

Hardness Testers. Riehle Testing Machines, Div. of American Machine & Metals, Inc., 4 pp, ill, No. RH-1154. Portable hardness testers for Rockwell readings with scales A, B, C, D, F and G. (227)

Pyrometer Wire Color Codes. Thermo Electric Co., Inc. Handy chart gives pyrometer color codes, calibration symbols and parts meeting ISA, military and aeronautical specifications. (228)

Hardness Testers. Wilson Mechanical Instrument Div., American Chain & Cable Co., Inc. Engineering data, uses and design features of Rockwell hardness testers. (229)

General

Decimal Equivalent Chart. John Hassall, Inc. Easy-to-read decimal-equivalent wall chart of this company's cold headed parts. (230)

Material Handling. Spaulding Fibre Co., Inc., 24 pp, ill. Describes line of fibre receptacles for material handling. (231)

Air Handling Equipment. The Spencer Turbine Co., No. 107-C. Data book on this company's equipment for the handling and use of compressed air. (232)

Temperature Measurement. Tempil Corp., 8 pp, ill. Compares various methods of temperature measurement, including temperature-indicating lacquer, crayons and pellets. (233)

Materials & Methods

March 1955

One point of view

Who should carry the research load?

As one travels through the industrial world around us, it becomes increasingly evident that more and better research is needed if we are to attain the economic, social and military goals that face us. The problems are extremely acute when we consider engineering materials. According to many engineers, progress in several fields is limited now because we lack materials which can perform the tasks expected of them.

We have touched upon this problem several times in the past. In fact, we once published a lengthy report citing some of the materials problems which needed to be solved. But our urgings were mainly for more fundamental research.

Now it becomes evident that much of the failure to provide adequate research must be blamed on materials producers. Too many producers of materials are satisfied to produce a sheet that looks good, is free of obvious flaws and which meets predetermined specifications as to chemical composition or minimum mechanical strength. That is not enough.

Any group engaged in the manufacture and sale of engineering materials should assume some of the responsibility for carrying on research which will provide materials of the future.

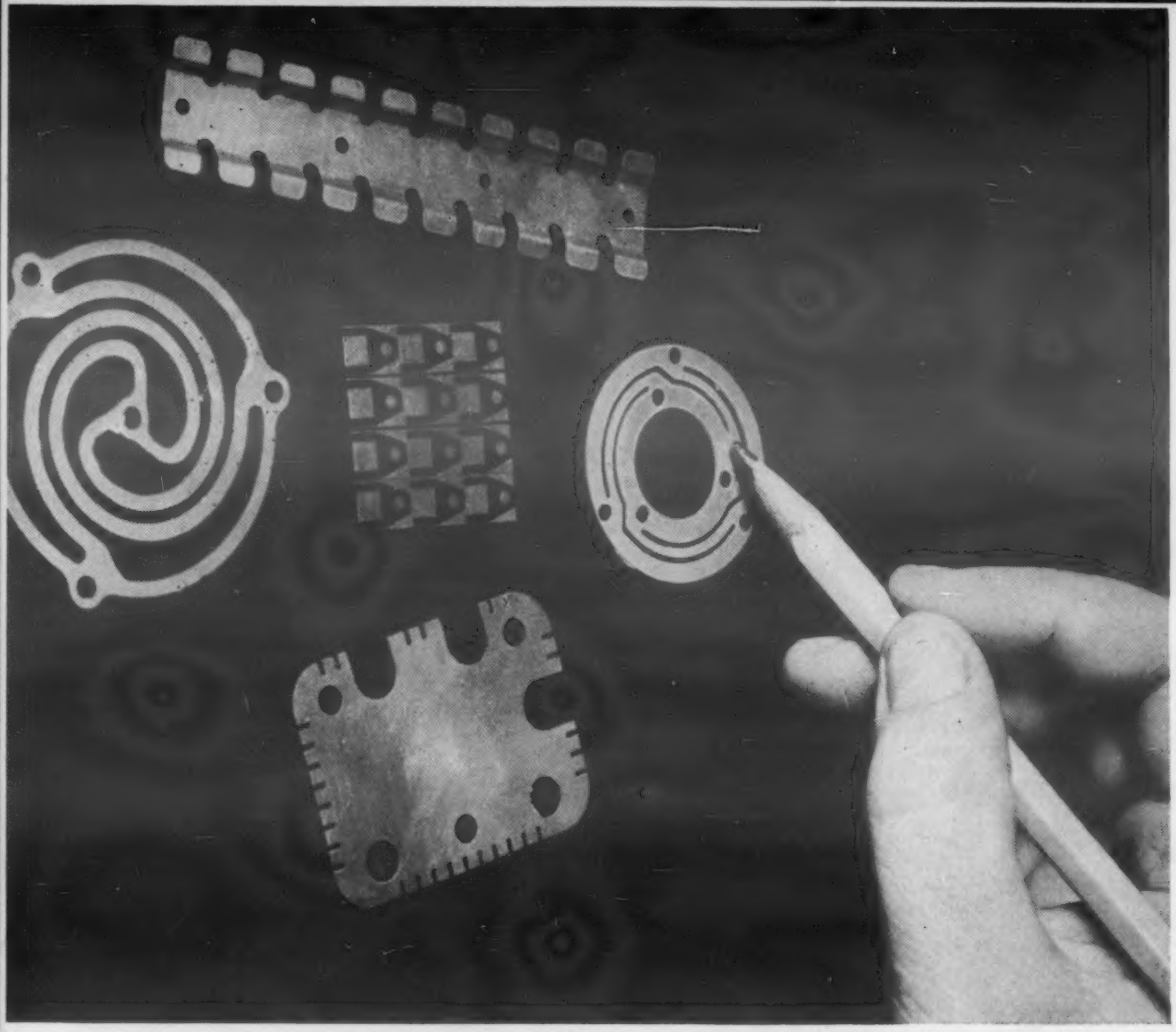
Before continuing, it might be well to point out that not all companies engaged in materials manufacture can be said to be lax in these areas. In fact, there are certain notable exceptions which merit strong praise. However, these are in the minority.

Recently it was pointed out that most of the basic research in the development of better metals was being done by the two leading manufacturers of electrical equipment. Several aircraft and automotive companies have found it necessary to develop special alloys to meet their specific requirements. More and more the consuming industries are turning to independent research groups to develop new materials.

When it comes to the proper use of materials, the picture is even more clear. Small companies which must fight for their lives develop the methods and techniques for better utilizing materials.

It would seem to us that the materials producers should take the lead in developing better materials and methods for processing them rather than waiting for the user to do the job. Such a development might be a natural outgrowth of the rapidly accelerating competition among materials for many applications.

T. C. Du Mond



Circuits—*Etched circuits make possible more flexible design of insulating parts. For example a circuit utilizing 0.016-in. wire would have resulted in a projection on the surface of a thin glass-reinforced laminate enclosing it. An etched copper circuit with the same current-carrying capacity, however, was only 0.005 in. thick. When bonded to 0.003-in. soft glass cloth, which was then laminated, it resulted in a thin flexible insulated circuit with no undesirable projections.*

'Stamping' Metals by Etching

Last October, M&M published an article describing North American Aviation's process for milling aluminum by alkali etching. Here is another etch-forming method—an acid etching process that can replace routing or stamping for many applications.

by Arthur Coleman,
Production Design Engineer,
Chance Vought Aircraft, Inc.

■ A new selective etching process is turning out many parts that would ordinarily be made by routing or stamping. The process consists of printing the shape of the desired part on flat metal sheet or strip with an acid-resistant ink, then etching away the unprotected metal to form the part.

Chief advantage of the etching process is that it eliminates die (or template) and set-up costs ordinarily involved in routing and stamping. Also, the time lapse from design to production can be reduced to a few hours or less. Savings can be achieved on both simple and intricate parts. Although savings are naturally greater for small quantities, they can also be achieved on fairly large quantities.

Etched "stampings" are made from flat material, but they may be postformed; the actual extent of forming depends on the design and on the limitations of the material itself. Greatest economies are achieved when as much of the complete assembly as possible is made as a single etched stamping.

Called "Chemi-Cut", the process was developed by Chance Vought Aircraft in cooperation with the Texas Nameplate Co. Key to the new process was the development of a suitable acid-resisting ink or compound. Existing materials were not good enough, and two new compounds had to be developed. With these compounds, clean, sharp edges can be obtained in etching and no after-trimming is needed.

In addition to savings in money and time resulting from elimination of dies and templates, the Chemi-Cut process offers:

1. Costs reduced by elimination of much labor and handling.

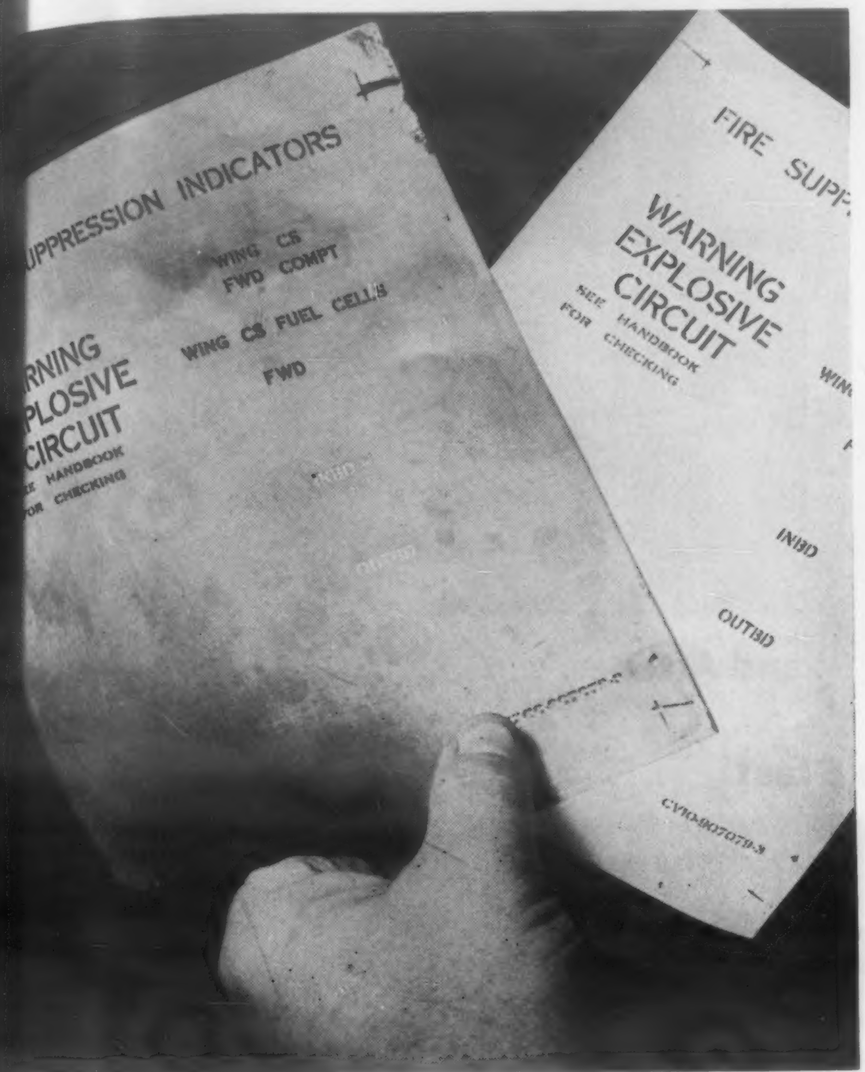
2. Materials waste reduced, since, by close nesting of parts, about 90% of sheet can be utilized, compared to about 75% in stamping.

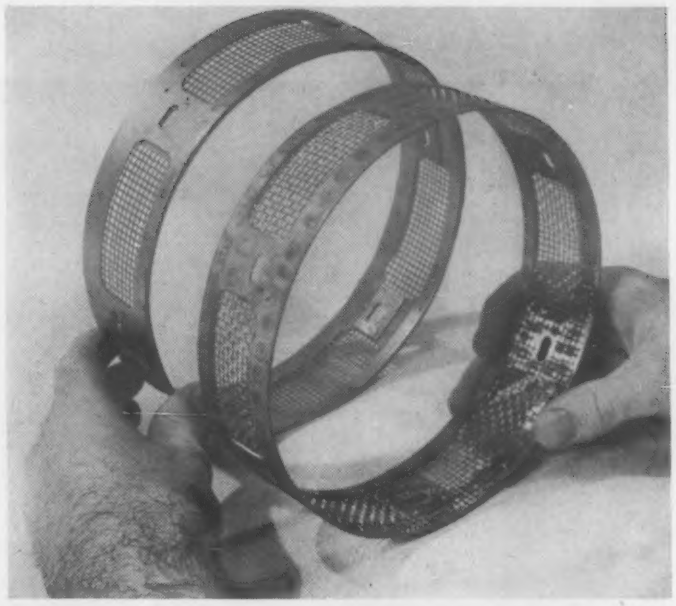
3. Assembly and inspection times reduced, rejects minimized, as parts are uniformly reproducible from master pattern.

4. Design changes made easily and inexpensively during production by revising engineering drawing and changing master pattern accordingly.

5. Configuration of part limited only by size and ability to be formed from flat material.

Stencils—*Etched metal stencils are being used for marking electronic chassis and other parts. The material is 0.005-in. brass shim stock. Such stencils are durable and relatively inexpensive, compared to paper or metal decals and, of course, neater than hand lettering.*





Screens—*Etched screens have replaced welded screen assemblies in several applications. For example, the air screen for the power plant generator in the F7U-3 formerly consisted essentially of a frame and six screens in which each individual wire strand had been spot welded (foreground above). The part required a total of 216 spot welds, and there was always a chance that a strand might come loose and eventually get into the engine. Now both frame and screening are etched from one piece of Type 302 stainless steel strip. Screening is integral and few spot welds are required to complete the part (background above). Similar results were obtained with a fuel cell screen.*

Although these parts were ready for use as etched, liquid honing of etched screens is suggested where operation is critical, as in hydraulic systems. Also, etched screen designs should provide for section moduli at least equal to those of conventional screen designs.

HOW IT WORKS

1. Make drawing of part. *Use black ink on dimensionally stable paper or cloth sheet. Recommended scale is usually four times actual size.*

2. Make photographic negative. *Vinyl-base negative recommended. Not always necessary; sometimes use transparent drawing itself as negative.*

3. Print part on material. *Use photo engraving, lithographing or silk screen processes with special acid-resistant ink or compound.*

4. Etch out part. *Expose surface of material to acid solution. Metal not protected by special ink or compound dissolves, leaving desired part.*

WHAT IT WILL DO

Materials etched: *aluminum, copper, bronze, brass, steel, beryllium, titanium, chromium-plated steel. Process believed to be applicable to any material except gold, silver, lead and platinum.*

Maximum thickness: *0.040 in. in two-stage etch; 0.020 in. in one-stage etch; 0.006 in. for vertical edge (thicker parts have shoulder with radius about equal to sheet thickness).*

Maximum size of part: *currently 27 x 30 in. or any combination of parts on sheet of this size.*

Etchant: *acid at ordinary temperatures. No details on etchant have been disclosed.*

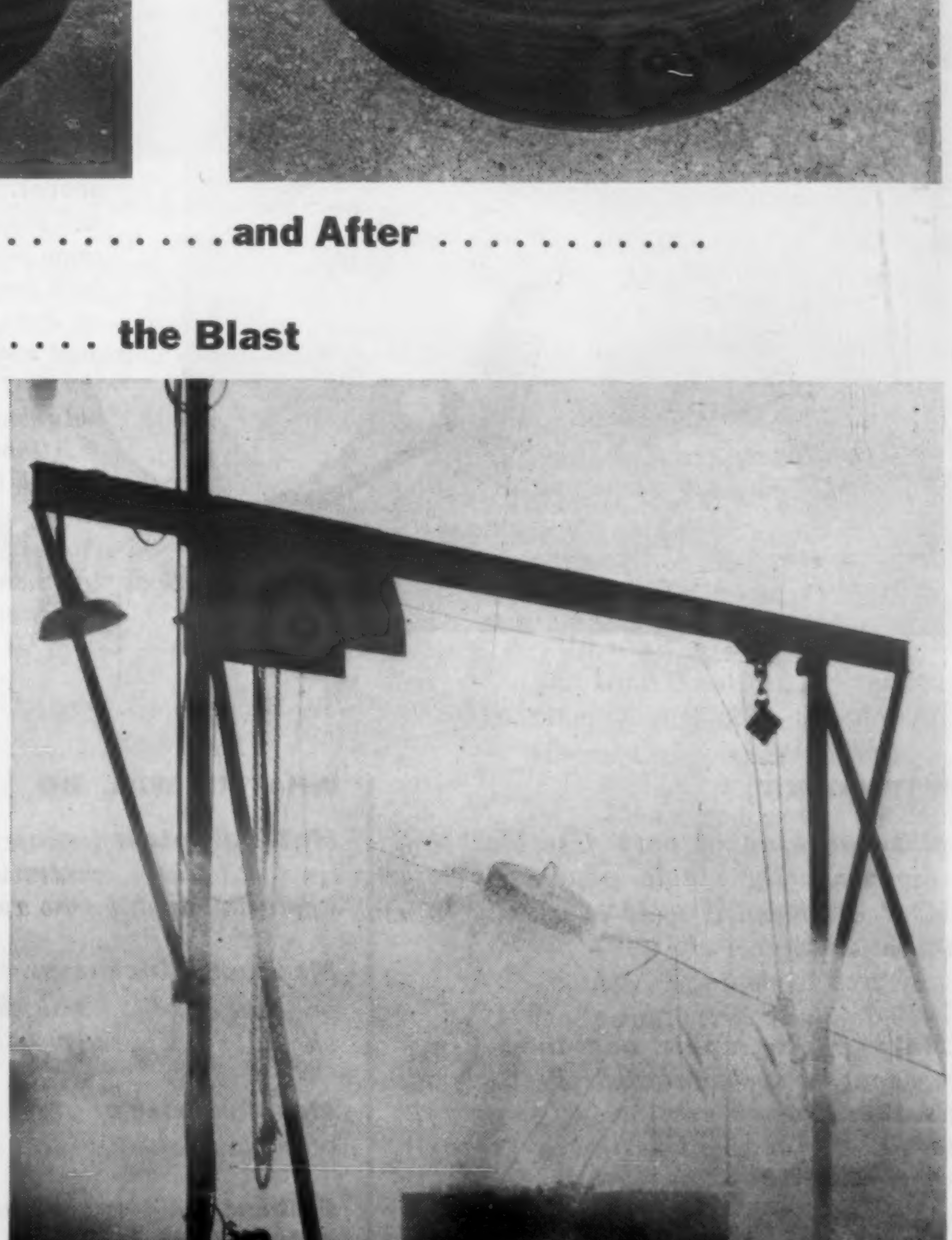
Etching rate: *about 0.001 in. per min. Can be doubled by 20 F increase in temperature of etchant.*

Cycle time: *from less than 30 min to a few hours following completion of master drawing.*

Cost savings: *up to 80% per part; even greater as parts become intricate.*

Monel Cylinder before . . . . and After . . . .

. . . . the Blast



This Monel cylinder is blasted into shape by dynamite to form the hub of a fan made by the Moore Co. Strips of Monel are first welded into cylinders such as the one on the left. Two of these are telescoped, one inside the other, and inserted into a laminated die partially filled with water. A stick of dynamite is suspended at water level, a heavy cover is placed over the die cavity and the explosion touched off. The resulting blast shapes the Monel metal to the contour of the die. The process resulted in a savings of 85% over the cost of spinning the fan hubs.

Housewares *are an important application for high-impact polystyrene sheet.* *(Dow Chemical Co.)*

Many Parts Made from

Thermoplastic Sheet

Today an increasing number of products are being molded from thermoplastic sheet. This article tells why. It also gives you a brief look at these materials and at what can be done with them.

by John B. Campbell, *Associate Editor, Materials & Methods*

■ Thermoplastic parts molded from sheet have replaced many parts formerly made of steel, aluminum, wood, rubber, glass, leather, cardboard and fabric. Typical products include tote boxes, advertising display signs, watch crystals, equipment housings, refrigerator door liners, carrying cases and acid-resistant fume hoods.

In some cases, they have replaced injection-molded thermoplastics. More often they are used where injection-molded plastics would be too expensive to be considered—namely, for parts of large projected area, parts to be made in limited quantities, or parts having extremely thin sections (on the order of 0.010-0.050 in.).

The current surge of interest in the forming of thermoplastic sheet is due to recent improvements in both materials and methods. Relatively low-cost extruded sheet has largely replaced more expensive cast or calendered sheet. Higher-impact materials, especially the modified styrenes and vinyls, have increased formability and design flexibility. Automatic, rapid-cycle vacuum forming machines have made sheet molding more suitable for longer production runs than ever before.

In sheet molding, flat thermoplastic sheet is preheated to temperatures in the range from 180 to 360 F, the temperature depending on the material, its thickness and the severity of the forming required. The hot sheet is then formed by mechanical, air or hydraulic pressure which is maintained until the sheet has cooled below its heat distortion temperature. Unwanted flange is sawed or blanked from the molded part, rough edges are sanded down and the part is then ready for whatever additional finishing or assembly operations are required.

Selecting right material

Since most of the common thermoplastics are sheet-molded to some extent, selection of a material can be based on a wide range of properties, appearance and cost. High-impact polystyrenes, rubber-styrene copolymer alloys, cellulose acetate, cellulose acetate butyrate, vinyl chloride-acetate copolymers, rigid polyvinyl chloride and acrylics are most widely used. The accompanying table gives data (primarily for comparison purposes) on properties and cost of these sheet materials, as well as polyethylene for which sheet molding

COMPARATIVE PROPERTIES AND COST

Property	ASTM	ORIENTED POLYSTYRENE	HIGH-IMPACT POLYSTYRENE	RUBBER-STYRENE COPOLYMER ALLOY	CELLULOSE ACETATE
Typical Tradenames, Suppliers		Polyflex[d], Plax Corp.	Styrene 475, Dow Chemical Co.; Campco S-300, Chicago Molded Products Corp.; Boltaron 7100[b] and 8100[b], Bolta Products Div., General Tire & Rubber Co.	Royalite 2000, U. S. Rubber Co.; Boltaron 6100, Bolta Products Div., General Tire and Rubber Co.; Ampcolite, Atlas Mineral Products Co.	S-704, Celanese Corp. of America; Kodapak I, Eastman Kodak Co.; Plastacele, E. I. Du Pont de Nemours & Co., Inc.; Midlon A, Midwest Plastic Products Co.
Specific Gravity	D 792	1.06	1.05	1.15	1.30
Thermal Conductivity Btu/hr/sq ft/ft/°F	C 177	—	0.07	0.08	0.14
Coef of Linear Thermal Exp. per °F (x 10^5)	D 696	4.0	4.4	4.7	6.0
Specific Heat, Btu/lb/°F	—	0.32	0.30	0.35	0.35
Index of Refraction (clear transparent)	D 542	1.59	—	—	1.50
Heat Distortion Temp at 264 psi, F	D 648	—	165	165	180
Mod of Elast in Ten, 10^5 psi	D 638	4.6	3.5, 2.5[b]	2.5	3.0
Tensile Strength, 1000 psi	D 638	10	3.5, 2.8[b]	4.2	7.0
Elongation (in 2 in.), %	D 638	7	18, 35[b]	25	35
Mod of Elast in Flexure, 10^5 psi	D 790	—	—	2.2	2.2
Flexural Strength, 1000 psi	D 790	10	6.3	5.8	8.5
Izod Impact Strength, ft-lb per in. of notch	D 256	3	0.8, 6[b]	10	2
Rockwell Hardness (Method A)	D 785	M90	M23	R87	R90
Dielectric Strength (1/8 in., short time in oil) v/mil	D 149	600	—	410	340
Dielectric Constant at 60 cycles	D 150	2.7	2.6	5.8	5.0
Water Absorption (in 24 hr), %	D 570	0.05	0.1	0.4	4
Resistance to Outdoor Exposure	—	Fair-Good	Low	Low	Low
Resistance to Chemicals	—	Good: weak acids, some strong acids, alkalis, alcohols. Poor: oxidizing acids, esters, aromatic and chlorinated hydrocarbons, some aliphatic hydrocarbons	Good: alkalis, salts, dilute mineral acids, lower alcohols. Poor: higher alcohols, gasolines, ketones, glacial acetic acid, oxidizing acids, unsaturated hydrocarbons, essential oils, aromatic and chlorinated hydrocarbons, esters, ethers	Good: alkalis, dilute inorganic acids, organic acids, alcohols. Poor: unsaturated hydrocarbons, ketones, ethers, acetates, chlorinated solvents, nitrohydrocarbons ,concentrated mineral acids	Good: greases, oils, hydrocarbon solvents. Poor: strong acids, strong alkalis, ketones, esters, chlorinated solvents, alcohols
Thickness Range, in.	—	0.001–0.020	0.005–0.250	0.010–0.500	0.003–0.250
Colors	—	Clear transparent, translucent white, all opaque colors	All colors, translucent, opaque	All colors, opaque	Clear, all colors, transparent, translucent, opaque
Finishes	—	Glossy	Glossy, matte	Glossy, matte, grained	Press polished, matte, linen, as extruded
Comparative Cost Index[a] per lb	—	0.86	0.65, 1.30[b]	1.45	0.92
per sq ft	—	0.22	0.18, 0.36[b]	0.42	0.32
Typical Applications	—	Light shielding, signs, container covers, toys, novelties, packaging	Freezer door liners, trays, advertising displays, toys, mannequins, TV tube masks, packaging, air conditioner and refrigerator parts	Luggage, sample cases, TV tube masks, tote boxes, acid tank hoods, fume exhaust pipes, displays, toys, appliance parts, shipping containers	Appliance parts, displays, specialty containers

[a] *Approximate cost based on 1000 lb order, 0.050 in. or nearest available size, uncolored, no special finish.*
[b] *Extra-high impact polystyrene. Applications same as rubber-styrene copolymer alloy.*

applications are not yet widely developed. Thin ethyl cellulose sheet is also being used, chiefly for flexible packaging. Virtually all cellulose nitrate products are made from sheet, but current applications are quite specialized. Although most thermoplastic sheet is now extruded or calendered, cast acrylic sheet is used where optical properties are important.

In general, if a part is to carry little or no stress, if it has a thin section of uniform thickness and relatively large area, and if it is to be made in limited quantities, there may be considerable advantage in making it from some type of thermoplastic sheet. Sheet is seldom suitable for parts requiring complex internal design, varying section thickness, undercuts or molded-in inserts.

OF THERMOPLASTIC SHEET MATERIALS

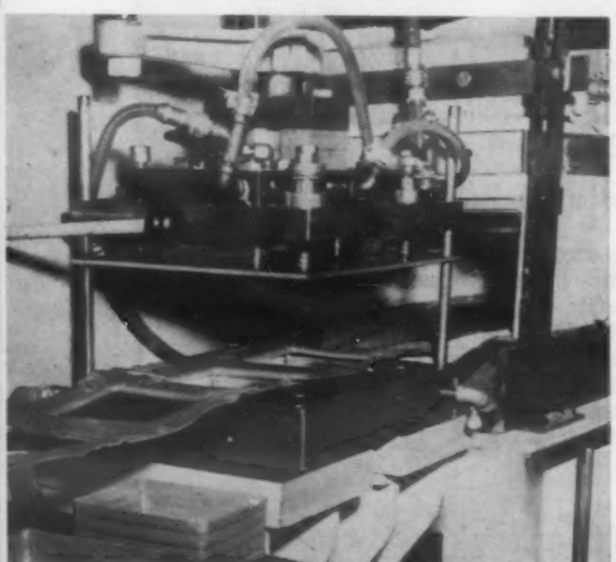
CELLULOSE ACETATE BUTYRATE	VINYL CHLORIDE-ACETATE COPOLYMER	POLYVINYL CHLORIDE	METHYL METHACRYLATE	POLYETHYLENE
Kodapak II, Eastman Kodak Co.; General Plastics Corp.; Midlon B, Midwest Plastic Products Co.; Nixon C/A/B, Nixon Nitration Works	Bakelite Co.	Boltaron 6200 and 7200[c], Bolta Products Div., General Tire & Rubber Co.; Ampoflex, Pee-Vee-Cee, Atlas Mineral Products Co.; Bakelite Co.	Plexiglas, Rohm & Haas Co.; Methaflex[d], Plax Corp.; Midlon M, Midwest Plastic Products Co.; General Plastics Corp.	Celanese Corp. of America; Atlas Mineral Products Co.
1.20	1.35	1.38	1.18	0.92
0.15	0.09	0.09	0.08	0.18
6.0	3.8	6.2, 4.5[e]	5.0, 4.2[d]	9.0
0.35	0.23	0.25	0.35	0.55
1.48	1.52	—	1.49	1.51
180	146	155, 164[e]	205	—
2.3	—	3.4, 4.6[e]	4.4	0.2
5.0	9.0	5.8, 8.5[e]	10	1.3
60	—	5	4	200
1.7	4.5	3.5, 4.5[e]	4.5	—
7.2	14	11, 14[e]	16	—
3	0.4	14, 0.7	0.4	No break
R90	—	R105, R117[e]	M93	R11
360	420	1090, 730[e]	500	460
4.6	3.3	4.0, 3.6[e]	3.5	2.3
1.5	0.08	—	0.3	0.01
Fair-Good	Fair	Excellent	Excellent	Fair
Good: greases, oils, hydrocarbon solvents, salts. Poor: strong acids, strong alkalis, alcohols, ketones, esters, chlorinated solvents	Good: inorganic acids, alkalis, alcohols, aliphatic hydrocarbons, oils, fats, waxes. Poor: organic acids, aromatic hydrocarbons, ethers, many other solvents	Excellent: oxidizing[c] and non-oxidizing acids, alkalis, salts, alcohols, oils. Fair: hydrocarbons, chlorinated hydrocarbons. Poor: ketones, esters	Good: alkalis, most dilute acids, aliphatic hydrocarbons, ethers, fats, mineral oils, foodstuffs. Poor: alcohols, aromatic hydrocarbons, esters, ketones, chlorinated hydrocarbons, strong oxidizing acids	Good: acids, alkalis, ketones, esters. Fair: greases, oils, hydrocarbon and chlorinated solvents
0.003-0.060	0.010-0.125	0.010-2.0	0.040-1.0, 0.010-0.020[d]	0.015-0.125
Clear	Clear, all colors, transparent, translucent, opaque	Clear[e], all colors	Clear, all colors, transparent, translucent, opaque, fluorescent	Translucent, opaque
Press polished, matte, as extruded	Press polished, matte, as calendered	Press polished, matte	Glossy	As extruded
1.11	1.18	1.77, 1.58[e]	1.80, 2.17[e], 2.37[d]	0.98
0.35	0.43	0.85, 0.75[e]	0.55, 0.67[e], 0.73[d]	0.23
Transparent containers, window display boxes, electrical insulation	Displays, face masks, motorcycle windshields	Dished tankheads, other parts for chemical process equipment, materials handling trays and covers	Outdoor signs, advertising displays, aircraft enclosures, equipment guards, switch and meter covers, toys, light filters, lamp housings and diffusers	Insulating shields, trays and containers for corrosive materials, toy parts

[c] *Formulated for optimum chemical resistance (Type I).*
[d] *Biaxially oriented.*
[e] *Cast.*

However, rigidity in large sections can be achieved by incorporating large radii, flanges and deep curved contour ribs in the design. Metal frames or trim are other strengthening devices.

One or both surfaces of unfinished sheet can be improved during forming if the forming method is such that the critical surfaces are pressed against smooth mold surfaces. Where optical properties are important, on the other hand, parts must be designed and forming methods selected to provide a minimum of mold contact. Finish of the original sheet can often be largely retained in a sheet-molded part, provided stretching is not excessive. Hence, many thermoplastic sheet materials are available prefinished. Most common finishes are matte, glossy

Print washer *consists of two pieces made from rubber-styrene copolymer alloy. Top is vacuum formed and bottom is made by plug-and-ring technique.* *(Bolta Products Div., General Tire & Rubber Co.)*



Cigarette boxes *stamped out by matched metal dies illustrate a method of forming high-impact polyvinyl chloride strip which may find broader application in the near future.* *(B. F. Goodrich Chemical Co.)*

and simulated leather-grain textures. Some companies, such as Coating Products, Inc., Gomar Mfg. Co. and Hy-Sil Mfg. Co., supply metallized sheet.

In determining thickness of sheet to be used, the engineer must consider not only the flexibility or rigidity required, but also the amount of "thinning out" that is likely to occur in forming, particularly in deep-drawn shapes. Excessive thinning out occurs when too small an area of sheet is available for stretching over or into a mold section, either because of mechanical impediments or because of too-rapid cooling of adjacent areas.

Thinning out can be controlled by the molder to a considerable degree. Some forming methods are naturally more susceptible to thinning out than others. Thinning can also be minimized by "slip forming", i.e., allowing additional material to slip into the mold during the draw, and by selective heating, i.e., heating to lower temperatures those portions of the sheet in which less flow and greater retention of thickness is desired. However, proper design is also important. Tapered walls and generous corner radii are very effective.

Selecting right method

An intelligent evaluation of sheet molding with respect to a particular part requires a certain degree of familiarity with the many and varied methods used to form thermoplastic sheet. The table briefly describes the basic methods and indicates some of the most important possibilities and limitations of each.

Other forming methods, not shown in the table, include "grease forming"—any method where the mold is coated with hot grease to minimize optical distortion; "hydraulic molding"—a method of forming the part by hot oil under pressure; and "Rotoforming"—Goodyear Aircraft's method of forming catenary-like shapes by stretching the hot sheet through a rotating die by means of air pressure.

Most experienced molders do not differentiate between "methods" as such, but merely combine whatever basic techniques are needed to achieve the desired result. Some of the most common combination methods are mentioned in the table. Many basic forming methods, including most of the trickiest combinations, have been developed to meet rigid optical specifications for transparent acrylic domes, noses and other aircraft windows.

For most commercial products, surface distortion caused by uneven stretching of material during forming is not critical and simpler forming methods are used. Although vacuum forming is currently holding the spotlight, many applications are better adapted to other, less publicized methods.

What most of these sheet forming methods have in common is low forming pressures and, consequently, low-cost molds and equipment. Metal molds and complex vacuum forming machines are sometimes used for long production runs, but generally the molds are wood, plaster or plastics, and the equipment consists of conventional small presses together with auxiliary jigs, frames, pumps, etc. Although thermoplastic sheet costs from 50 to 100% more than the corresponding injection molding compounds, higher materials cost is easily offset by lower fixed cost for limited production runs. Low mold cost not only makes sheet molding particularly advantageous for small quantities, but also enables economical design changes to be made during production.

Sheet molding, particularly a

precision method like vacuum forming, has an additional cost advantage over injection molding for parts that are to be finished in more than one color after forming. By silk-screening or other processes, the colors can be applied in distortion to the flat sheet and brought into correct registration automatically by the forming. This technique eliminates costly individual finishing of formed parts.

Not all sheet forming methods feature low mold cost. Matched metal die molding involves expensive steel dies and is not suitable for low production runs. However, this method shows promise for quantity production of relatively small parts at lower cost than would be possible by either injection molding or vacuum forming. Matched metal die molding of boxes from continuous 0.050-in. high-impact polyvinyl chloride strip was demonstrated by B. F. Goodrich Chemical Co. at the National Plastics Exposition last year. The plastics strip was fed automatically through a strip heater to a conventional metal stamping press equipped with water-cooled two-cavity dies. This set-up not only formed but stamped out the two halves for as many as 6 or 7 boxes a minute. A number of metal fabricators are reported to be interested in this method.

Acknowledgment

The assistance of the companies named in this article is gratefully acknowledged. The help provided by Eastman Chemical Products, Inc. and Steiner Plastics Mfg. Co. is also appreciated.

BASIC METHODS OF FORMING THERMOPLASTIC SHEET*

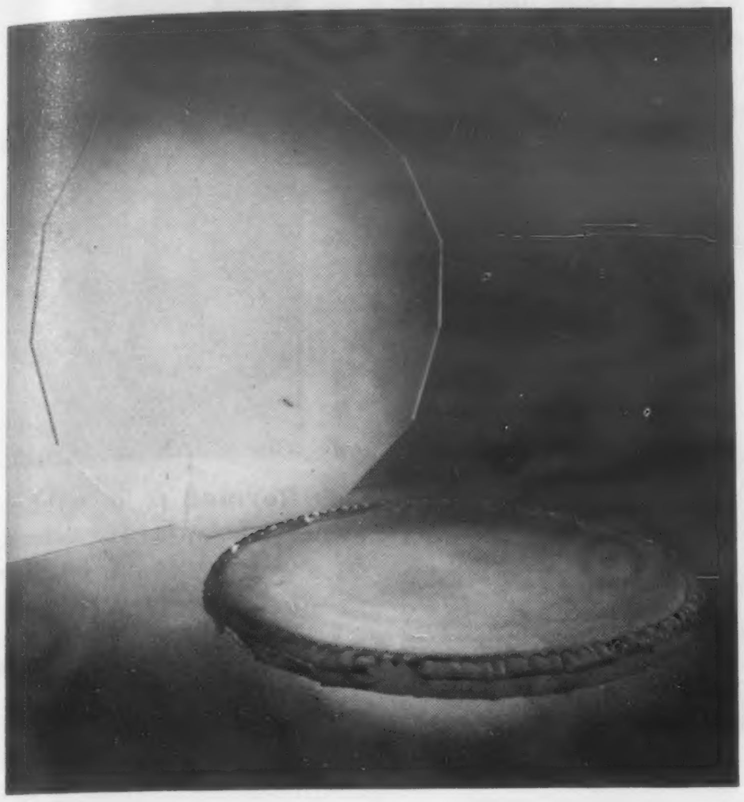
How They Work	What They Can Do
Cold Bending Cold sheet bent manually or mechanically and secured in place by adhesive or mechanical fasteners.	Simple circular or cylindrical shapes. The thicker the sheet, the larger the bend diameter must be to prevent high stress concentrations. Ex: consumer packages.
Hot Line Bending Sheet heated locally along straight line by strip heater, creased in V-groove or otherwise bent mechanically to desired angle, and held in place until cool.	Two-dimensional shapes with arc, angle or channel cross sections. Gradual to sharp bends, depending on heating procedure. Ex: safety guards.
Stretch Forming (hot draping, yoke forming) Hot sheet fitted with clamps at edges, stretched manually (sometimes up to 10 men) over male plug, and held by clamping ring until cool; or (yoke forming) clamped in yoke, lowered mechanically over male plug, and held there until cool.	Two-dimensional or slightly compound shapes, especially large shapes. Subject to surface distortion. Not suitable for reproduction of fine details. Yoke forming provides more uniform thinning out; suitable for longer runs than manual stretch forming. Ex: aircraft canopies.
Plug and Ring Forming Hot sheet clamped over cavity by ring of radius equal to plug radius plus sheet thickness plus small clearance allowance. Male plug lowered into sheet to form plug contour. Plug remains in place until sheet is cool. First part of draw sometimes done by vacuum.	Shallow to deep-drawn shapes with gradual to sharp angles and curves. Not suitable for highly accurate contours or fine mold details. Considerable surface distortion, especially at inside corners—unsuitable where optical properties critical. Ex: trays.
Slip Forming Same as yoke forming and plug and ring forming except that clamping pressure is controlled to allow predetermined amount of material to slip through the clamping frame onto the plug during the draw.	Same as yoke forming or plug and ring forming except that much more uniform thickness and less optical or pattern distortion can be obtained throughout the part, especially in deep-drawn shapes. Fluted edges obtained by increasing clearance. Ex: carrying cases.
Free Blowing or Free Vacuum Forming Hot sheet clamped over vacuum pot or pressure head and drawn or blown to desired depth of draw. Vacuum or pressure held until sheet is cool.	Somewhat modified surface tension shapes (tending toward fishbowl shape) determined by shape of clamping ring and depth of draw. Internal flanges. Tolerances ¼-½ in. Good optical properties. Vacuum method easier to control and preferred where 15 psi is sufficient pressure. Ex: aircraft domes.

*Listed in approximate order of increasing cost for small quantities.

(Continued on page 104)

BASIC METHODS OF FORMING THERMOPLASTIC SHEET (continued)

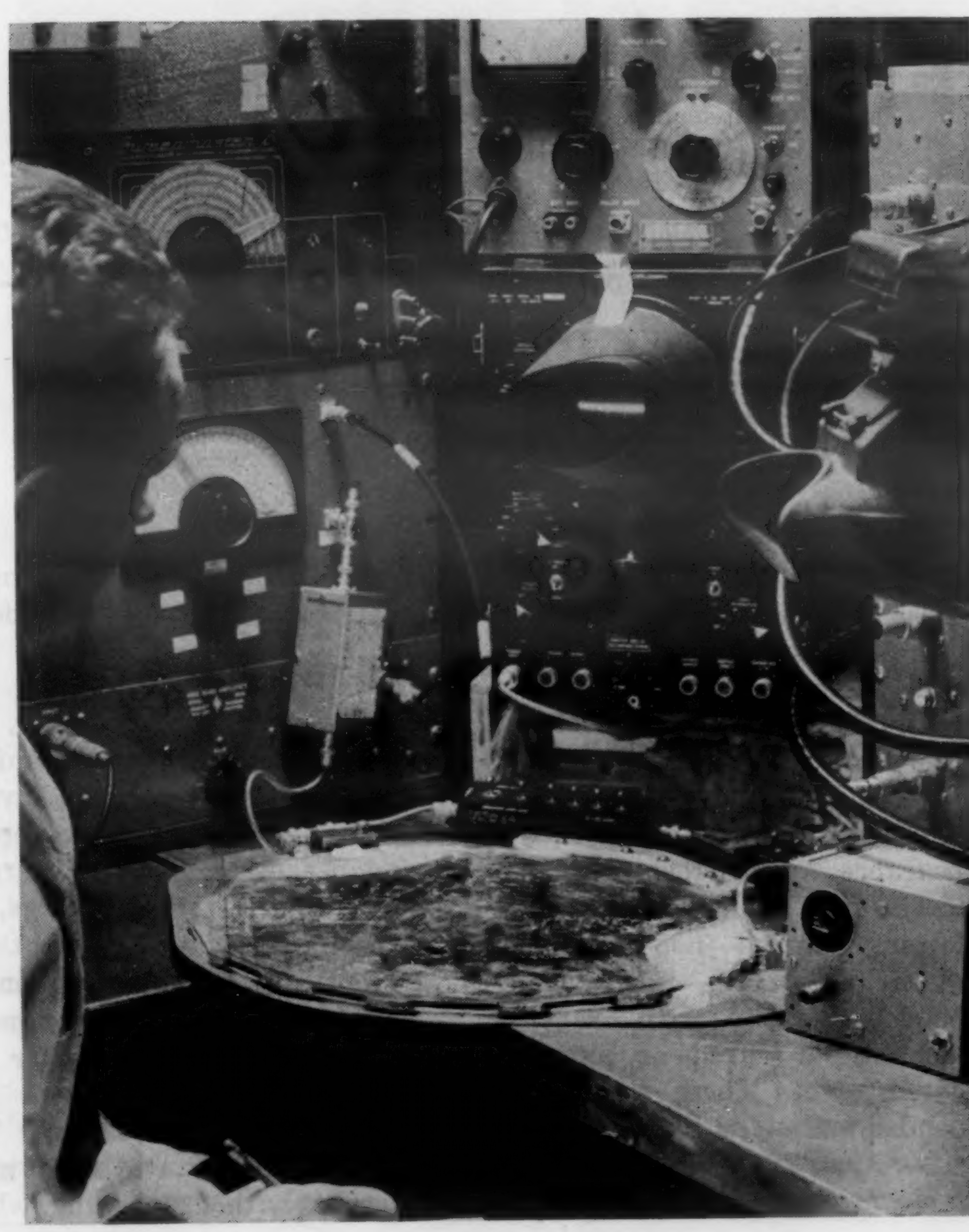
How They Work	What They Can Do
Ridge Forming Hot sheet clamped over cavity and stretched into it by skeleton male plug (contacts sheet only where necessary to produce desired shape) which is held in position until sheet cools. Sometimes draw supplemented by vacuum or air pressure to produce concave or convex surfaces between contact ridges. Sometimes skeleton female mold also used with vacuum or air pressure. First part of draw sometimes done by vacuum.	Simple or complex (with vacuum and/or air pressure) shapes with minimum surface distortion and low mold cost. Generous radii necessary to avoid tearing at ridges during forming. Combines possibilities of plug and ring forming, free blowing or free vacuum forming, vacuum forming and vacuum snapback forming. Ex: equipment housings.
Vacuum Forming or Blow Molding in Female Mold Hot sheet clamped over female mold and drawn or forced into mold by vacuum (10-13 psi) or air pressure. Vacuum or pressure held until sheet cools. Machine with automatic heating-forming-cooling cycle sometimes used.	Usually limited to relatively shallow draws, and relatively large angles and radii—more so the thicker the sheet. Blow molding offers higher pressures and is therefore more suitable for smaller angles and radii, especially in thicker sheet; also reduces forming temperature required for thick sheet. Both produce some surface distortion—less so the more the shape of the mold resembles a surface tension shape. Ex: display signs.
Blow-Dieing Sheet softened by hot water, clamped over split two-piece female mold, stretched into it by plunger, and expanded against mold by steam pressure. Sheet cooled by cold water.	Small, thin shapes having greatest perimeter larger than neck—especially closed spherical or modified spherical shapes. Not suitable for close tolerances. Ex: hollow toys.
Vacuum Forming Over Male Plug (drape forming) Hot sheet, clamped in frame, lowered on to male plug and drawn to male plug contour by vacuum (10-13 psi). Vacuum held until sheet is cool. Split male plug may be used for undercut shapes. Machine with automatic heating-forming-cooling cycle sometimes used.	Shallow to deep-drawn shapes with relatively sharp angles and curves can be made with good accuracy, good reproduction of fine mold detail and without excessive thinning out. More accurate than plug and ring forming but not as suitable for thick sheet. Subject to surface distortion especially at bottom of draw. Ex: display signs.
Vacuum Snapback Forming Hot sheet clamped over cavity and drawn partially into cavity by vacuum (10-13 psi). Male plug lowered into sheet concavity and vacuum released. Sheet "memory" snaps it back against male plug which is held in place until sheet is cool. Sometimes sheet forced against male plug also by reverse vacuum or by air pressure.	Especially suitable for modified surface tension shapes with minimum mark-off and closer tolerances (1/8 in.) than obtainable in free blowing or free vacuum forming. Simple snapback method not suitable for reverse curves or sudden contour changes, but more complex shapes and finer reproduction of mold detail are provided by additional vacuum or air pressure. Integral flanges. Combines possibilities of free vacuum forming and plug and ring forming. Ex: aircraft domes.
Matched Die Molding (embossing) Hot sheet compressed (up to 2000 psi) between matched male and female dies and held under compression until sheet cools.	Especially suitable for shallow draws, long runs and embossed surfaces. Relatively uniform thickness, good mechanical properties. Subject to surface distortion on both sides. Ex: watch crystals.
Die Pressing Pre-blanked hot sheet (sharp corners removed by tumbling) compressed between closed dies at pressures (up to 2000 psi) sufficient to cause plastic flow. Dies remain closed until material cools.	Small, simple shapes that can be approximated in precut blank and have somewhat varying thickness, or relatively great thickness compared to overall size. Ex: brush backs.



Fused Silica Makes Largest Delay Lines

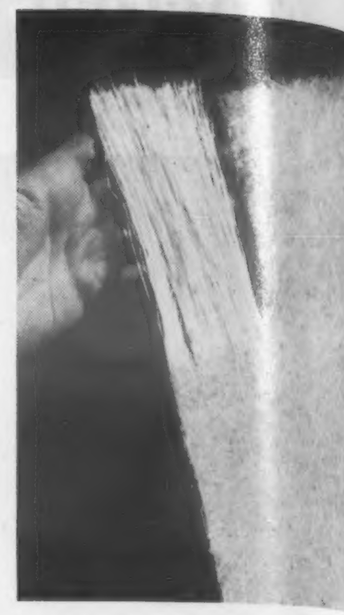
Fused silica is used by Corning Glass Works to make these large ultrasonic delay lines. The lines provide a delay of 3333 microseconds in transmission of electrical signals. Thin polygon sheets of fused silica (standing in background at upper left) are cut and ground to tolerances up to $\pm$ 0.0003 in. from boules of fused silica similar to the one shown in foreground of same picture.

After testing (bottom), the fused silica lines are mounted and cushioned inside an aluminum casing. An electrical signal takes as long to pass through one of the thin 20-in. dia delay lines as it would to travel by wire from New York to Detroit.



Format: *Twisted a full turn in one foot, a 2-in. wide cutting of 8 oz Format holds its shape, shows no springback. Note thickness of mat.*

Fabmat *is a glass-fiber, non-directional mat attached to a base of woven glass fabric. The material has good strength properties before and after molding.*



Rovmat *is a mechanically-bonded, non-directional mat on a base of unidirectional rovings. With tension in the direction of the rovings, the mat can be pulled through resin bath and squeegee rollers for impregnation.*

Three Types of New Mechanically-Bonded

Fiber Glass Mat

New plastic reinforcing material contains no chemical binder . . . Has improved drapability, better wetting-out, greater uniformity, broader range of weights.

by L. M. Calhoun, *Manager, Bigelow Fiber Glass Products Co.*

■ Selecting the right form of glass fiber reinforcing material for plastics moldings is important. Reinforcing material ranks with resin quality in determining the physical properties of moldings, and it can have a major influence on production costs, appearance, and performance.

The most common form of reinforcing material—non-directional glass-fiber mats—are usually bonded lightly with varying amounts of cured or partially cured resin. These chemically-bonded mats tend to vary in density. Also, the choice of molding resin may be limited to those compatible with the chemical binders supplied by the mat fabricator.

Advantages

Mechanically-bonded mat, developed by the Bigelow Sanford Carpet Co.'s Fiber Glass Div., is made of sized glass fibers chopped and needled into a thin carrier mat, unidirectional rovings, or woven glass fabric. The three types of mechanically-bonded mat fit almost all current molding requirements and offer the following advantages:

1. Improved drapability. The mats will conform to sharp mold contours without bridging, which sometimes causes crazing at corners. The mats will not spring back from concave mold contours. Better drapability has allowed molders to eliminate costly preform operations in many applications. Also, because of the mat's pliability even in heavy weights, one thick layer will replace multiple layers of chemically-bonded mat, eliminating multiple cutting and lay up steps.

2. Better wetting-out. Mechanically-bonded mat wets-out quickly by wicking. Liquid resin poured in the center of a mat will spread evenly throughout the thickness of the entire fabric,

while chemically-bonded mat, often has a hardened surface that tends to resist penetration. Chemically-bonded mat is more difficult to wet-out because the fibers have been subjected to a cured or partially cured resin; it is also hard to obtain a good bond between aged and fresh resins, and delamination problems increase. Complete wetting-out of each individual fiber is a major prerequisite to the molding of uniform translucent, decorative sheets.

3. Broader range of weights. Mechanically-bonded mats can be produced in practically an unlimited range of weights. Molders have used thicknesses up to 10 oz per sq ft without difficulty. In contrast, resin-bonded mats over 2 oz in weight are ordinarily too stiff to conform to mold cavities.

4. Reduced inventories. Since mechanically-bonded mat is compatible with any type of resin, it is not necessary to stock a variety of mats containing various types and amounts of resin binder to conform to each application and type of resin used.

5. Greater uniformity. Quality control is essential for mass produced moldings. Mechanical mat is manufactured with a tolerance of +10%; however, actual manufacturing tolerance is closer, with uniformity improving in the heavier grades.

Properties

The good wetting and bonding characteristics of mechanically bonded mat permit higher glass-to-resin proportions with minimum sacrifice in strength.

Average test results for standard ASTM test section of polyester resin reinforced with mechanically-bonded mat (resin: glass ratio 1:1) are:

Flexural Strength 32,000 psi (± 3000)
Tensile Strength 20,000 psi (± 2000)
Flexural Modulus 1.6 x 10^6 (± 0.2)

The wet-strength retention of mechanical-mat-reinforced plastic components is very high due to the close resin-glass bond. With chrome, or regular sizes, tensile strength is reduced only 50% in the ASTM 2-hr boil test. From 75 to 85% of dry tensile strength is retained after the boil test in samples with high-performance silane sizing.

Tests on standard sections laminated of three layers of 2-oz mat or made from a single section of 6-oz mat show no significant difference in physical properties. Sections made of a single heavy layer of mechanically-bonded mat are, for practical purposes, superior to laminated sections of thinner mat, since there is no delamination hazard.

Forms of mat

Mechanically-bonded mat is produced in three configurations called Format, Fabmat, and Rovmat. All mat is sized (see box) with any of the commercial sizings, and can be obtained in a special "textured" form at slight extra cost.

Format is a non-directional, general-purpose mat. It consists of a controlled blend of chopped roving mechanically bound to a thin carrier mat. It is versatile, and is used in practically all types of molding and laminating applications. It is available in weights from 2 oz per sq ft up to almost any weight desired, although 10-oz mat is the heaviest manufactured for

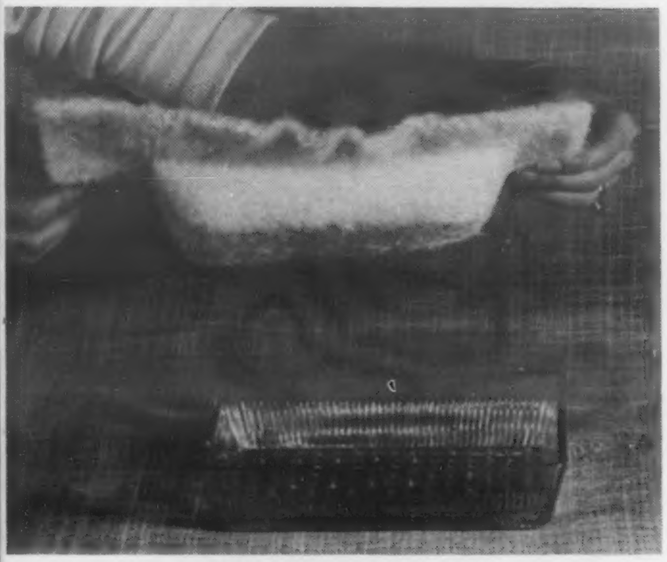
Sizing, Finish, and Binders

There is a general tendency in the reinforced plastics industry to confuse fabric finishes, fiber sizings, and resin binders. The three are distinguished as follows:

Sizing—Size is applied to the fiber as it is formed. Glass fibers are commonly drawn from the melt 204 at a time, sized immediately on a roller, and bunched into a group called a sliver. A sliver is the basic strand of fibers used for roving, yarn, mat, etc. The sizing acts as a lubricant to keep the fibers from abrading, and also lends greater toughness and flexibility to the sliver. In addition, the size serves as a binder to keep the fibers together and aligned in the sliver. In manufacturing glass fiber yarns (twisted slivers) a sizing of starch and lubricant is used which is incompatible with molding resins. It is necessary to remove sizing from woven fabric or twisted yarn by heat and/or chemical cleaning. The fabric is subsequently *finished*, q.v., so that the molding resin will bond to the fibers. Fibers (and slivers) not intended for twisting or weaving are sized with standard chrome salts or high performance silanes and may be used for reinforcing plastic moldings without further processing.

Finish—Finishes are applied to fabrics only, after they are woven. Fabric finishes for reinforced plastics are essentially the same as the sizings applied to fibers that are not woven—either chrome salts or silanes. Because finishing is easier to control than sizing (due to the high speed at which fibers are drawn over the sizing roller) plastic moldings reinforced with finished fabrics usually exhibit better strength characteristics than sized mat and roving, even though the sizing and finishing compounds do not differ significantly. These extra finishing steps are more costly and some discoloration occurs in heat cleaning.

Resin binders—Resin binders are used in chemically bonded mat to hold the fibers in place during lay up, cutting and molding. Molding resin must match the binding resin in chemical properties in order to wet out the mat and effect a proper cure. Mechanically-bonded mats do not use resin binders. They are sized only.



Drapability *of mechanically-bonded glass fiber mat is demonstrated by pressing heavy 8-oz Format into a dish. Note how all-glass mat retains its shape, resembling a preform, when removed.*

Boat hulls *are formed with pressure bags in female molds, or by diffusion molding, in which the mat is laid up, the molds closed and evacuated, and the resin is allowed to flow into the mold from troughs. Fabmat is particularly adaptable to diffusion techniques.*
(Winner Mfg. Co.)

Contact molded *horse from female mold laid up with 2-oz format. Drapability of material simplifies molding of sharp contours found in hoofs and ears of horse.* *(Exhibit Supply)*

use to date.

Rovmat is a high tensile-strength, unidirectional mat which has continuous strands of roving uniformly distributed in a longitudinal direction on a base of chopped strands and light carrier mat. Standard Rovmat has 60-end (60 sliver) rovings spaced five to the inch, though other configurations of ends and spacing are available. Rovmat is suited for high tensile and/or burst strength applications, and makes a good preformed sandwich material, as the roving is spaced closely on the surface, presenting the appearance of a nearly solid, unidirectional sheet. Rovmat is produced in weights of 3 oz and up. Typical applications include pipe, fittings, tubing, deep draw products, long unsupported shapes, pre-impregnated mats, and sandwich constructions.

Fabmat is a base layer of woven or unwoven glass fabric to which the controlled blend of chopped fibers is attached mechanically. Since any type of glass fabric can be used, the material is about as close to being a preform for sandwich work as is possible. It eliminates time and labor of cutting and matching multiple layers of cloth and mat. Fabmat provides unusual strength properties before, during and after impregnation and molding. Its fabric carrier is strong and consistent for pre-impregnating processes. After molding, the fabric contributes greatly to the strength efficiency of the product, as well as its appearance. The mechanical bond between the non-directional mat and the woven fabric is believed to contribute to the excellent resistance to delamination of the finished sandwich. Typical applications include pressure vessels, pipe, deep draw items, and pre-impregnated mats.

Molding

Mechanically-bonded mats are compatible with all molding processes. A typical contact molded assembly and various vacuum bag techniques are pictured.

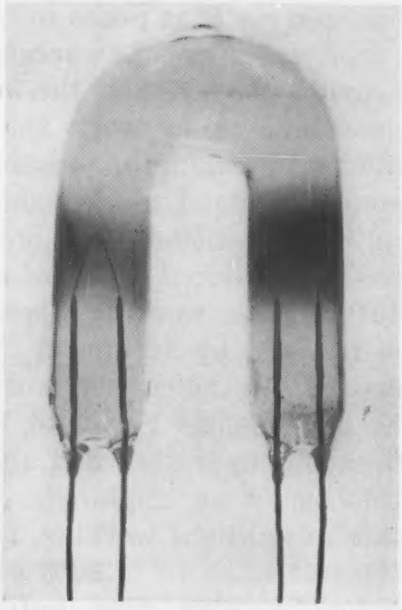
Matched-metal die molding has more critical variables than contact or vacuum techniques. Until recently, mechanically-bonded mats sacrificed some strength during the molding cycle when resin was applied, due to the lubricating action of the liquid. Resin flow during die closure can result in a condition known as "wash"—the fibers are carried with the flowing resin. A new process for mats, known as texturing (mentioned above) has substantially eliminated wash problems by increasing the resin-wet tenacity of the fibers. Texturing is not a resin binder finish and does not affect wetting or cure properties.

When using mechanically-bonded mat for matched-metal molding, it is wise to take precautions against washing even with textured mat. Such precautions include: avoiding puddling the resin in one spot; placing the male portion of the mold on the bottom; and slowing down the closure rate of the dies as much as possible. The heaviest weight mat should be used, with good die pressures to overcome the natural resilience of the mat.

As a rule of thumb in match metal die molding, one ounce of mat weight laminates to 1/64 in. thickness for 1 to 1 resin-glass ratios. In actual practice a 65 to 35 resin-glass ratio laminates to 1/8 in. with 6-oz mechanically-bonded mat.

Mechanically-bonded mat is a significant step toward providing mass production molders with a uniform reinforcing material. Because it contains no chemical binder the mat is physically tailored for general molding operations rather than for particular resins and lends itself to a wide variety of applications. Mechanical mat permits reduced inventories, yet at the same time increases flexibility of operation, since all mats are compatible with any resins or molding techniques. Precut patterns are also available to cut costs and reduce waste and inventory even further.

Electron Tubes
Electrical Contacts
Pens
Corrosion Applications
make use of—



***Evacuated tube** showing the relative resistance of rhenium (left) and tungsten to the "water cycle".*

Rhenium Metal

With development of suitable fabricating techniques, the interesting physical, mechanical, chemical and electronic properties of this new metal are now being exploited.

by Chester T. Sims, *Principal Metallurgist, Battelle Memorial Institute*

■ Rhenium, generally considered a laboratory curiosity less than a year ago, has joined the ever-growing group of new materials whose properties fit them for special applications. Recent advances include electrical contact materials for use in marine engine magnetos, while a number of electronic applications are under development.

Relatively recently, rhenium has been found to occur in several localities throughout the world in addition to the original supply source at Mansfeld, Germany. These include the Republic of Kazakh, in Siberia, and the states of Nevada, Utah, New Mexico, and Arizona in the United States. Rhenium occurs as a sulfide in its native state, closely allied with molybdenite and usually in the presence of copper.

Rhenium's metallurgical position is among the commercially expensive but high-performance metals. If its use continues to expand at the present rate it is quite conceivable that in a few years total U. S. production will be of the order of 5 tons per year. This is small compared with many metals but is an appreciable quantity for a semi-precious metal.

Other than at the University of Tennessee, no prices have yet been released for rhenium metal, but it is probably safe to assume that despite rather expensive recovery and fabrication processes, rhenium will be available on the market at a price somewhat below that of platinum ($1300 per lb).

Properties

Certain general properties of rhenium are compared to the same properties for tungsten and molybdenum in the accompanying table. Among metals rhenium is second in melting point only to tungsten. It is very dense, has one of the highest Young's moduli known, and possesses high annealed tensile strength combined with excellent ductility at room temperature. Its strength increases up to 300,000-350,000 psi with increasing cold work, but even at these high strength levels it retains 1 to 2% elongation. Hardness values climb rapidly with increasing cold work. Its work-hardening characteristics are compared with those of nickel in a graph to indicate this effect.

Rhenium also possesses superior high-temperature strength properties, but unlike tungsten and other high-temperature metals, exhibits a decrease in ductility with increase in temperature. This probably is a manifestation of its hot shortness. The metal does not become fully brittle, however, and always retains 1 to 2% elongation. Rhenium, because of its volatile oxide and hot shortness, must be protected by a vacuum or a reducing or nonoxidizing atmosphere when exposed to high temperatures.

Certain basic electronic properties have been determined. The thermionic work function of rhenium is slightly higher than that of tungsten. The addition of thoria lowers the work function as it does for tungsten, but present information indicates that thoriated tungsten is a more efficient emitter of electrons.

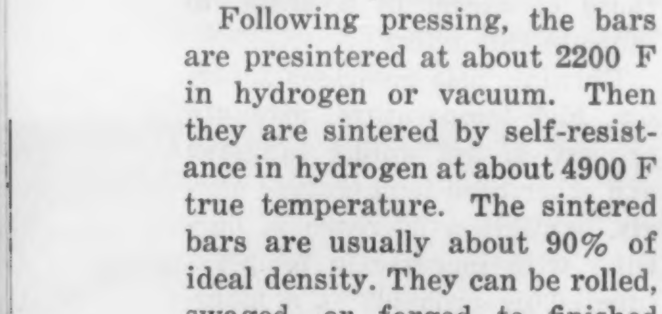
Fabrication

Despite optimistic statements in the past that rhenium metal is both hot and cold workable, this has not been found to be wholly correct in recent work. Rhenium forms a heptoxide Re_2O_7, which is a liquid above

567 F and volatilizes at 685 F. Evidently because of the liquid oxide phase, rhenium appears to be hot short in air no matter how pure the metal or what the hot-working conditions. This has eliminated hot working from present consideration and led to cold fabrication techniques.

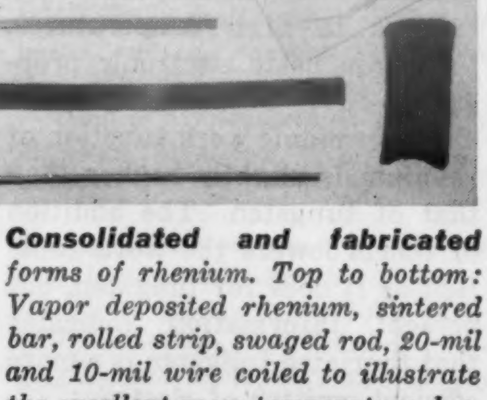
The process currently in use involves concentrations of the rhenium from raw ore through a series of chemical operations until highly purified ammonium perrhenate is prepared. This salt is reduced with hydrogen to fine rhenium metal powder, usually of —325-mesh particle size. The powder is compacted at high pressures, about 30 tsi, into bars which are usually about 40% of ideal density and very fragile. Currently, ¼ x ¼-in., ½ x ½-in. and ⅛ x ½-in. bars have been successfully pressed.

Following pressing, the bars are presintered at about 2200 F in hydrogen or vacuum. Then they are sintered by self-resistance in hydrogen at about 4900 F true temperature. The sintered bars are usually about 90% of ideal density. They can be rolled, swaged, or forged to finished shape cold, but only with a great deal of care.



***Consolidated and fabricated** forms of rhenium. Top to bottom: Vapor deposited rhenium, sintered bar, rolled strip, swaged rod, 20-mil and 10-mil wire coiled to illustrate the excellent room temperature ductility. To the right, rolled sheet.*

***Magnetos** containing rhenium contacts.* *(Gale Products Division, Outboard Marine & Manufacturing Co.)*



Rhenium work hardens probably more rapidly than any other known metal. As a result, the sintered metal is prone to transverse cracking if worked too heavily. Apparently, the safest procedure is to work the bar lightly by rolling or pressing in steps of about 1 to 3% reduction in cross-sectional area until it has been reduced a total of about 10%. Each working operation is followed by an anneal in hydrogen. In the current work, ½ hr at 3100-3300 F is used, but a higher temperature and shorter time could be employed. After this initial light working, reductions of from 10 to 20% can be given on each pass until the desired shape is reached. Intermediate anneals after the heavier passes are for sufficient time to reduce the surface hardness below 300 VHN. This requires about 2 hr at 3100-3300 F.

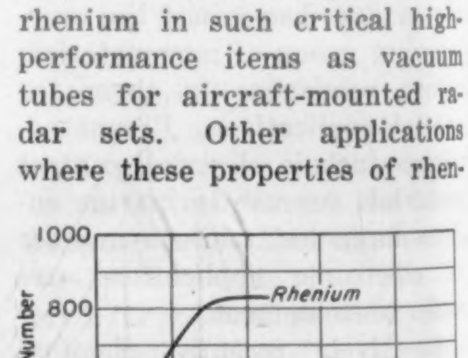
In general, rhenium appears to be most amenable to fabrication by rolling. It has been rolled to 3-mil foil with very little edge cracking. Rhenium also swages well, but friction-type operations, such as wire drawing, are difficult to perform. If metal of extremely high purity is not needed, experience has shown that nonmetallics such as thoria ease working difficulties considerably, possibly by refining the grain size and lowering the recrystallization temperature. For instance, 0.5 and 1.0% thoria added to rhenium, have caused a considerable increase in fabricability. These additions caused only a slight reduction in strength, ductility, and high-melting properties.

Applications

Some evaluation of rhenium in applications aimed at industrial use of the metal have been made recently. One of the most striking of these has been conducted by Wyler, Gideon, and Todd in connection with the performance of rhenium as a filament or other component in electron tubes. Tungsten, a common electron-tube construction material, is prone to attack by residual water vapor in a thermochemical phenomenon called the "water cycle". Briefly, water vapor reacts to form tungsten oxide on the hot tungsten filament and the oxide is volatilized and deposits on the tube envelope, where it is reduced to tungsten metal, freeing water which "cycles" back to continue its deleterious attack.

To compare rhenium and tungsten, a U-tube was prepared with the right leg containing a tungsten filament and the left a rhenium filament. The tube was evacuated, but contained a small amount of water vapor. The filaments were heated to identical temperatures, about 3275 F, for a long period of time.

An accompanying photograph shows how much more tungsten was transferred by water cycle than rhenium. In general, this means than rhenium can operate as a filament much closer to its melting point than can tungsten, despite the difference in vapor pressures. It also means that for any given temperature when water vapor is present, rhenium should be a longer lived, more dependable filament than tungsten. This characteristic combined with the fact that rhenium remains ductile at any temperature while resistance increases with temperature—thus permitting heavier sections in filaments, may soon result in application of rhenium in such critical high-performance items as vacuum tubes for aircraft-mounted radar sets. Other applications where these properties of rhen-



Cold work-hardening characteristics of rhenium and nickel.

PROPERTIES OF RHENIUM, TUNGSTEN AND MOLYBDENUM

	Rhenium	Tungsten	Molybdenum
PHYSICAL PROPERTIES			
Melting Point, F	5756	6170	4757
Boiling Point, F	10,652	10,706	8672
Vapor Pressure (at 4000 F) mm Hg	1×10^{-6}	1×10^{-7}	4×10^{-4}
Density lb/cu in.	0.756	0.695	0.367
Electrical resistivity microhm-cm	19.5	5.5	5.2
Temp coef of resistivity at 68 F	1.73×10^{-3}	2.2×10^{-3}	1.8×10^{-3}
Electrical conductivity % I. A. C. S.	9.25	32	31
Coef of Expansion 68-925 F	3.7×10^{-6}	2.5×10^{-6}	3.0×10^{-6}
Thermionic Work Function a, e.v. (at Richardson Constant of 52, 49, and 115 respectively)	4.80	4.56	4.37
Crystal Structure	Hex. close packed	Body centered cubic	Body centered cubic
MECHANICAL PROPERTIES			
Modulus of Elasticity, psi	67×10^6	50×10^6	49×10^6
Tensile Strength (annealed) psi	170,000	125,000	60,000
Elongation (annealed), %	25	Low	Low
Vickers Hardness (annealed)	250	250	160
Vickers Hardness (worked)	800	500	250

ium could improve performance are in light-source devices such as photographic projection lamps and railway headlamps.

In late 1953, Todd and coworkers, as part of the current work, placed rhenium in series with tungsten and platinum-ruthenium electrical contacts and evaluated its performance under conditions closely approximating those found in circuit breakers operating under 8 amp and inductive loads. After operation, the rhenium was in excellent condition, while the other metals were inoperable.

The superlative performance of rhenium as an electrical contact material is ascribed primarily to the following factors:

1. High melting point and boiling point which minimize the effects of arc erosion at contact surfaces.
2. Excellent resistance to corrosion under widespread atmospheric conditions.
3. High hardness and ductility which provide increased resistance to impact and mechanical wear.
4. A unique conductive oxide (ReO_3) which forms under conditions of electrical-contact service, thereby enhancing surety-of-make.
5. A lower degree of arcing than most common contact materials, including tungsten, because of the combination of high work function and advantageous oxide characteristic.

It is noteworthy that rhenium exhibits a desirable balance of properties combining the corrosion resistance of the precious metals with the high hardness and favorable arcing characteristics of tungsten. These characteristics account for superior behavior in marine engine magnetos which are subject to salt atmosphere corrosion as well as to impact, mechanical wear, and electrical erosion. This particular application is the first known commercial use of rhenium as an electrical-contact material.

Cast alloys of rhenium have been used for pen points in Europe in years past. A number of other uses for the metal are still under consideration. For instance, cold-worked rhenium is extremely tough and wear resistant, and could be made available in a much greater variety of fabricated shapes than cast alloys such as osmiridium. Rhenium also seems to be highly resistant to molten metals. Investigations to determine whether the metal would perform well as a vaporization filament are under way in an industrial concern and first reports are very promising. The use of rhenium in x-ray tubes is also being studied. It was seriously considered as a component in thermocouples in pre-war Germany, although that field is relatively quiet now.

Electronically, as mentioned above, the pure metal is not quite so efficient an emitter as tungsten. However, it may exhibit superior properties as the major component in the so-called "impregnated" cathodes, and a certain amount of work is moving in this direction.

Acknowledgment

Most of the basic data summarized in this article are a result of research at Battelle Memorial Institute. This work is supported by the Aeronautical Research Laboratory of the Wright Air Development Center. All of the rhenium metal used was kindly donated by the Kennecott Copper Corp. P. R. Mallory & Co. has materially assisted in the development of rhenium as an electrical-contact material.

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***Foamed-in-place** cellular plastics provided in two-component kit. Small quantities in test tubes are combined to create foam in container at right.*
(Curtiss-Wright Corp.)

New

Polyester-Isocyanate Synthetics

are being produced as:

1. Elastomers with excellent oil and abrasion resistance.

2. Foam plastics with close density control.

3. Coatings with high toughness and wear resistance.

by Kenneth Rose, *Midwestern Editor, Materials & Methods*

■ A new polyester resin has been developed which can be reacted with di-isocyanates to produce a number of different plastics products having a wide range of properties.

Developed and widely used in Germany, these polyesters were recently introduced into the United States. A new company, Mobay Chemical Co., jointly owned by Monsanto Chemical Co. and Farbenfabrikent Bayer, A.G., has been formed to produce the basic chemicals and to furnish technological information on their use in the American market. Here, their applications thus far have been limited to industrial products whereas applications in Europe have already been extended to consumer products.

The new polyesters are essentially linear esters of adipic acids and glycols. The various formulations possible with isocyanates result in plastics possessing an unusually wide range of properties and corresponding applications varying with the formulation selected. For example, the finished product has softening points ranging from 180 to 300 F, depending upon the formulation; and, burning rate varies from slow burning through self-extinguishing to nonflammable according to the formulation selected. The different types of plastics forms that can now be produced are: solid elastomers; rigid and flexible foams; lacquers; adhesives; and enamel for magnet wires.

Solid elastomers

This group of solid rubber-like materials is at present limited to cast forms in both hard and soft types. They have excellent oil and abrasion resistance. Because of their high cost, they will probably be limited at present to industrial applications where these two special properties are needed. Timing gear belts, oil seals, sleeves for moving parts in engines, hydraulic gaskets, special gears and sole and heel material for military boots are typical

European uses. Scientists estimate that it will eventually be possible to produce auto and truck tires with a tread life of 100,000 miles from these elastomers at a price competitive with rubber tires.

Foam plastics

Both rigid and flexible foamed materials can be produced with polyester-isocyanate combinations. The reaction between the two resins produces carbon dioxide as the expanding agent.

One of the most important properties of this group is its capacity for close density control through regulation of the amounts of isocyanate and other ingredients used in the reaction. Both open and closed cell types are produced which vary in density from 1 to 2 lb per cu ft to 30 lb per cu ft. For thermal insulating purposes the density may be held as low as 1½ lb per cu ft, while for structural purposes a density of about 8 lb per cu ft is generally used. The insulating quality of the foam is indicated by its K factor of 0.20 to 0.30. Other properties include:

Tensile strength, 100-500 psi
Compressive yield strength, 100-500 psi or more
Moisture absorption, about 1% in 24 hr

Rigid foams have high compressive strength and excellent adhesion to most structural materials. They are used for both structural strength and heat insulation. In some cases they may be foamed in place, as in inside wing tips of aircraft, to serve as low-density core materials. A high-speed articulated train now under construction in Germany uses cars constructed of thin aluminum sheet facings over polyester-isocyanate foam cores. This same sandwich is being studied as construction material for a refrigerator truck that will have as much heat insulating value as heavier sheathings now in use, with considerable decrease in dead weight.

Flexible foam is a light-weight material. It is only about half the weight of foam rubber of equal volume and equal load bearing. Flexible foam also has slower recovery after compression than foam rubbers. This property, sometimes called "no swimming," refers to the foam's cushion quality as compared to the extreme live quality of sponge rubber. It is strong enough to be sewn and otherwise fabricated without backing and may therefore be less costly to process than natural or conventional synthetic foams.

Flexible foam may be produced in large blocks or split into thin sheets on standard leather-splitting machines. Sheets as thin as 1 mil and less may be split, but 2 and 3 mil thicknesses are more common. Such sheets are used as interliners in winter coating, and sheets of ⅛ in. to ¼ in. thickness are used as carpet underlay.

In Europe this foam is used for pads for operating tables, topper pads for innerspring mattresses and automobile upholstery. In these uses, there is no film or skin directly covering the sponge which permits better ventilation. As sponges they are excellent since they do not absorb water into the voids and material, but take up water into the air spaces only, and have a long life.

Coatings

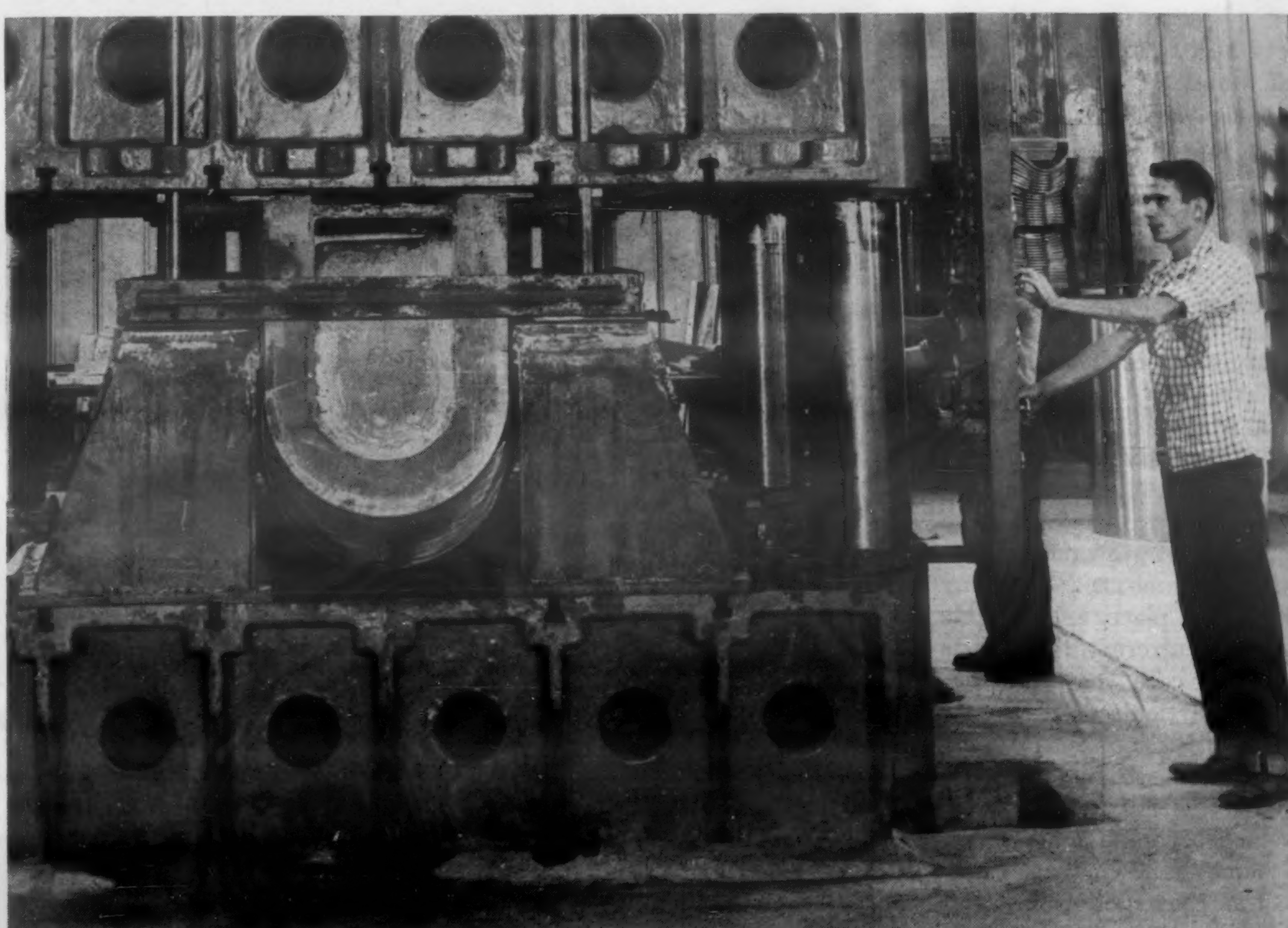
Polyester-isocyanate combinations provide air drying lacquers of high luster and extreme toughness. They will be useful in applications where excellent wear resistance is required, such as floors, paint equipment in chemical plants, steel mills, oil tanker cargo holds, etc.

The electrical and physical properties of these enamels are excellent and their moisture resistance is better than that of most current finishes now in use. Potential uses are coatings for magnet wires used to wind motors, transformers and coils.

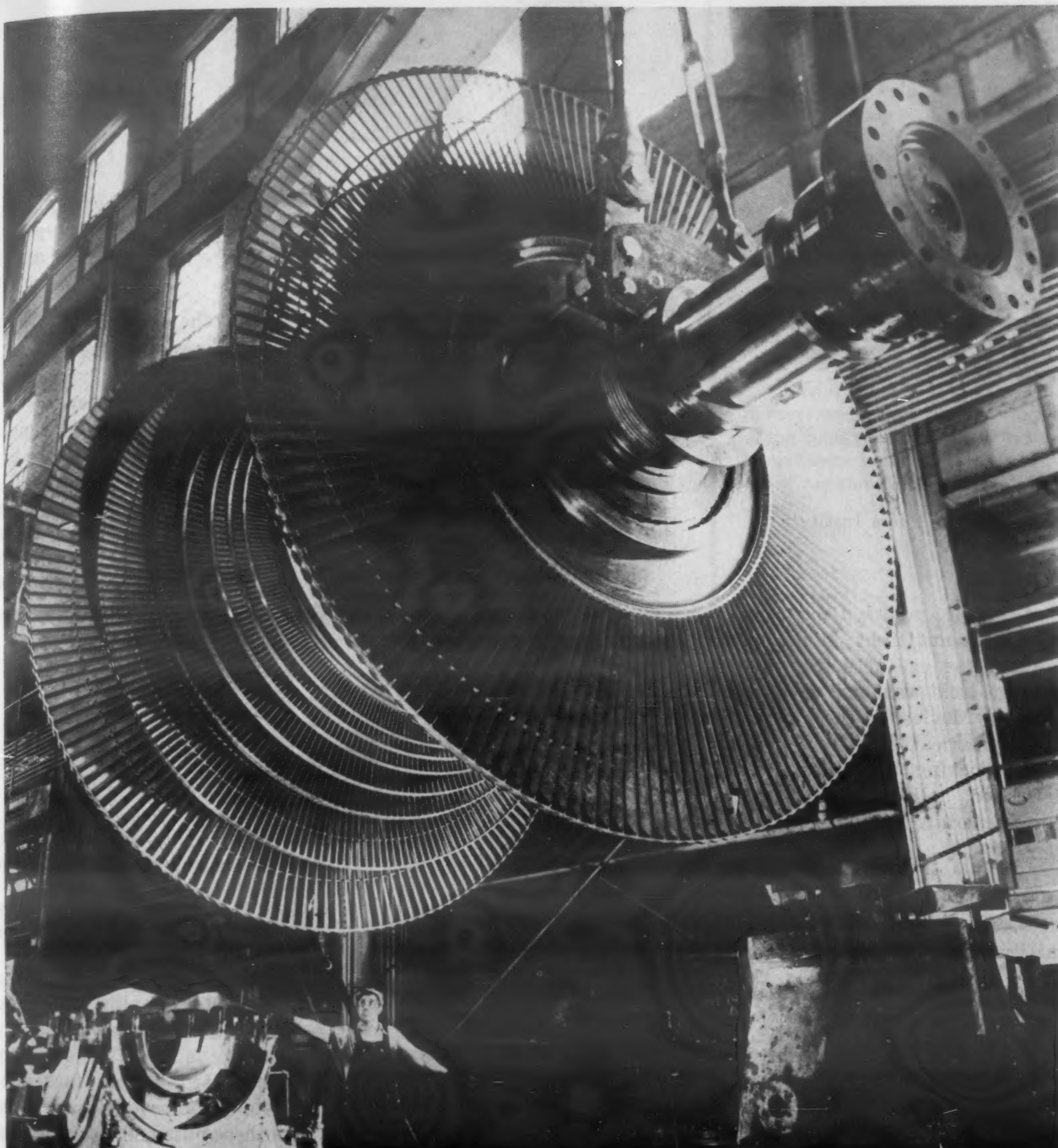
Flexible and rigid *cellular plastics are possible with these new resin combinations.* *(Curtiss-Wright Corp.)*

Biggest Rubber Press Pad?

Said to be the heaviest homogenous forming pad ever made and cured in one piece, 4650 lb of vulcanized crude rubber is being hoisted for shipment to Boeing Airplane Co. It will be used on a 5000-ton press to form aircraft parts under a pressure of 1100 psi. Manufactured by U. S. Rubber Co., the pad is 11 in. thick, 5-½ ft wide and 12-½ ft long.

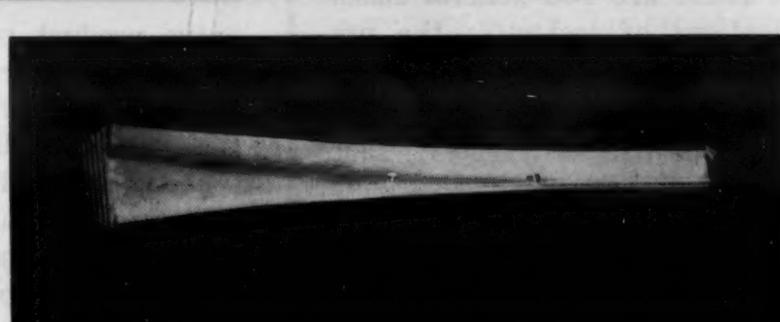


Giant Plastics Die—This plastics draw die is more than 14 ft long and 5 ft deep, tapering to about 3 ft at its small end. Die face is glass-reinforced epoxy, backed with cast phenolic and mounted on a steel frame. Estimates place the total weight of a metal tool of this size at 60,000 lb. Total weight in plastics is 18,000 lb. The die was fabricated, from drawing board to production, in less than 60 days. Built by Tru-Scale, Inc., it is being used at Beech Aircraft Corp.



Cobalt-Base Alloy Guards Turbine Blades

Tips of the blades on this turbine travel at around 1265 ft per min. Used at the cold end of steam turbines, blades traveling at such speeds are subject to severe erosion from condensed particles of moisture. Allis Chalmers Mfg. Co. uses hot-rolled strips of cobalt-based Haynes Stellite alloy 6B to protect the 13% chromium stainless steel blades. The 40-in. blade shown has a 27-in. strip of Alloy 6B silver-soldered to the leading edge. One such turbine was recently inspected after 19 yr of service and the blades were found to be in good condition.



Keep your fasteners tight with

Locknuts

There are many types. Usually best test of proper selection is how well it works in given job.

by Staff,
Industrial Fasteners Institute

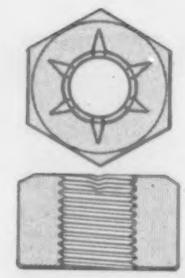
■ A simple, practical means of keeping a nut tight on its bolt without the use of cotter pins, wiring, lock washers or other auxiliary devices is the locknut. Many practical, effective designs of self-locking nuts have been developed, and are being used quite generally on a wide variety of products.

To differentiate between *locknuts* and any other locking devices, the Industrial Fasteners Institute has defined a locknut as "a device that acts in the manner of a nut and has a special means for gripping a threaded member so that relative motion between the nut and the threaded companion member is prevented in use."

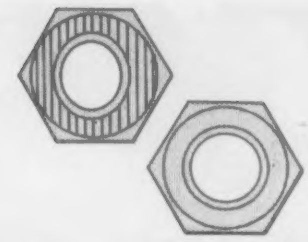
There are two general classifications of locknuts: the *prevailing-torque,* and the *free-spinning.* Both classes include many types and designs. Some representative ones are illustrated in this article.

Because of the demonstrated advantages of locknuts, wide use is being made of them by manufacturers of machinery and equipment of all types. From jet fighters to lawn mowers, from electronic instruments to earthmoving machinery, locknuts improve product performance, reduce manufacturing costs, eliminate service and maintenance expense. Locknuts are used in typewriters and dictating machines, textile shuttles and looms, conveyors, automotive equipment, diesel engines, pumps, ordnance equipment, home appliances, railroad equipment, bicycles, mining machinery, radio and TV sets, toys, heavy presses and cranes, farm equipment—wherever parts must be held together under conditions that would tend to loosen regular nuts.

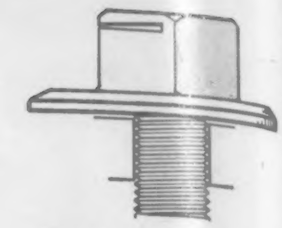
Selection of locknuts for specific applications should be placed in the hands of qualified engineers. No one design has yet been found that is best for all applications. Often the best test of a locknut is how well it works in a given job. Cost is an important consideration—but as is frequently true in industrial work, the most expensive unit may be cheapest in the long run.



Deformed thread type, in which depressions in the face of the nut distort a few threads.



Upper portion made slightly out of round provides gripping force.

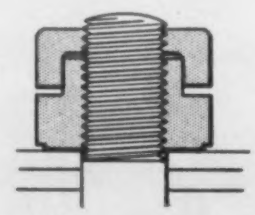


Slotting and deforming upper part of nut provides gripping force.

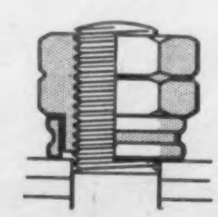
Prevailing-torque types

Prevailing-torque locknuts spin freely for a few turns, and then must be wrenched to final position. They reach their maximum holding locking power as soon as the threads and the locking feature are engaged, and retain them until the nut is removed from the bolt.

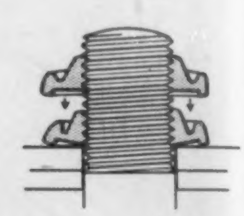
Several basic principles are used in the design of prevailing-torque locknuts. One consists of deflecting a few threads. This causes friction to develop when threads are mated, and thus resists loosening. In another type, a similar effect is achieved by making the top portion of the tapped nut slightly oval instead of round. When wrenched, the out-of-round section grips the



When upper half of nut is tightened it presses collar of lower half against bolt.



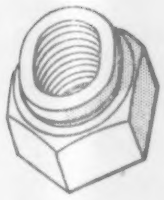
A grooved washer causes threaded collar to move in and lock radially on bolt when nut is wrenched tight.



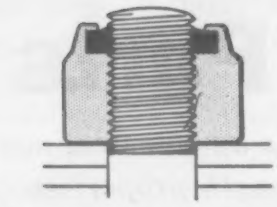
Two positions of a "diaphragm" type locknut, before and after seating. Bending action causes upper threads to grip bolt.

Free-spinning types

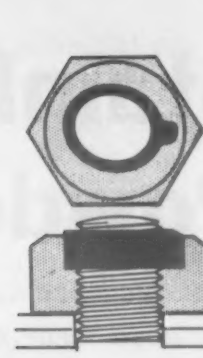
As the name implies, free-spinning type of locknuts are free to spin on the bolt until seated. Some of these consist of two mating parts that wedge together upon tightening against each other or against the work, thereby developing an inward pressure on the bolt. Other free-spinning locknuts have a curbed or recessed bottom face and a slotted or grooved upper portion. As these nuts are drawn up tight



Out-of-round threaded collar above regular load-bearing threads grips bolt.



Nonmetallic collar clamped in top produces locking action.

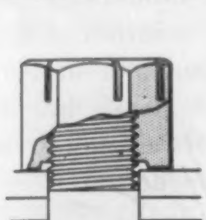


Threaded eliptical spring steel insert in top grips the bolt.

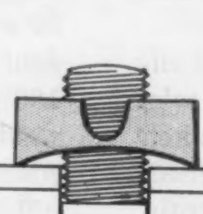
bolt threads, and resists rotation. A third type has the upper portion slotted and pressed inward. The "fingers" provide a spring frictional grip on the bolt.

Several types of prevailing-torque locknuts employ non-metallic or soft metal plugs or rings which are retained in the locknut. These are plastically deformed by the bolt threads and thereby provide frictional interference and thread pressure that prevents rotation in use.

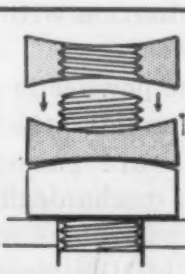
All of these types generally have the advantage of versatility. They spin freely for a few turns and must then be wrenched to position, where they will remain, whether seated or not, until they are removed by wrenching.



"Diaphragm" type, in which tight wrenching produces locking action by deflection of upper part.



Arched bottom causes top to pinch-in and bind, to produce locking force.



Seating-lock nut, applied over a regular nut. Locking force comes from thread distortion when firmly seated.

against the work, a spring or diaphragm action develops in the nut, causing the threads of the upper portion of the nut to pinch-in and bind on the bolt.

When pressure against work is relieved, most types of these nuts resume their original shape.

There are, however, some types that take a permanent set upon seating, and therefore become in effect a prevailing-torque nut, and will not move when the pressure against the work is removed.

Light spring-action locknuts

The locknuts described above generally provide the full holding strength of conventional nuts. But there is another group of locknuts which are of a light spring construction, and which are used for locking action where high strength is not required. There are several designs of these devices of both the prevailing-torque and the free-spinning types. Very often they have the advantage of adding speed to the fastening process, as well as providing security from loosening.

Single-thread type of lock-nut which is speedily applied. Locks by grip of arched prongs, when bolt is tightened.

Where Locknuts Proved Successful

. . . in a jet engine thermocouple connection, high temperatures and high vibration caused loosening. A free-running locknut cured the trouble without thread seizure or nut loosening.

. . . for the mounting of a semiautomatic washing machine, a saving of 87% in assembly time was secured by using a spring-type locknut.

. . . manufacturers of power lawn mowers use hundreds of thousands of locknuts per year for motor-mountings, handles, wheels and other fastening. Adopted to resist loosening and for economy, factory testing and field surveys have shown results to be satisfactory.

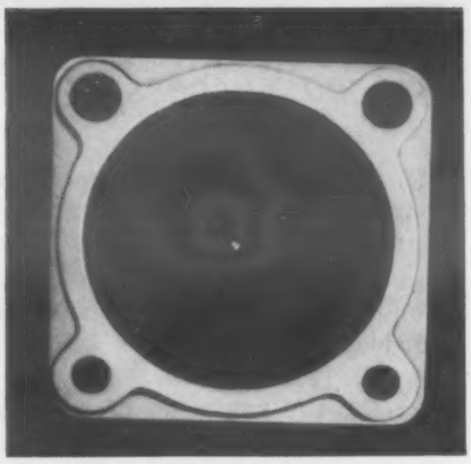
. . . thirty per cent was saved in the total cost of a metal cabinet through the use of light spring-action locknuts. The former method of assembly employed tapped holes in the mild steel, which stripped excessively. Locknuts corrected this.

. . . locknuts reduced assembly time from 20 min to 68 sec, when they replaced two 1-in. slotted nuts on a front switch rod. In this case, inaccessibility made assembly with slotted nuts particularly difficult.

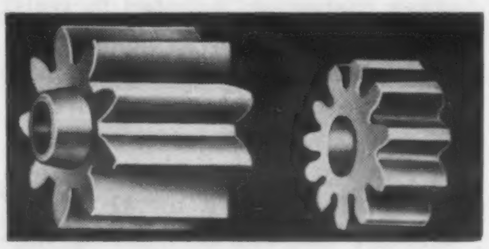
. . . relatively light metal parts such as automobile fenders, radiators, etc., subject to considerable shock and vibration, are securely and economically fastened by properly applied locknuts.

. . . in a portable electric hammer, vibration, shock load and impact were very severe. The use of prevailing-torque type locknuts eliminated loose fasteners, improved the product and permitted exact and permanent adjustment of a fastener that locked in position on top of spring-loaded pins.

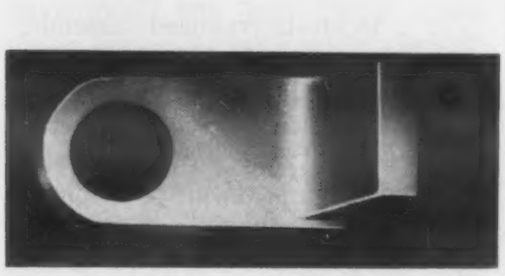
. . . a unique use of locknuts is for electrical connections on a transformer switch which is immersed in oil, causing a difficult maintenance problem. With locknuts, there has been no vibration loosening and product performance has been improved.



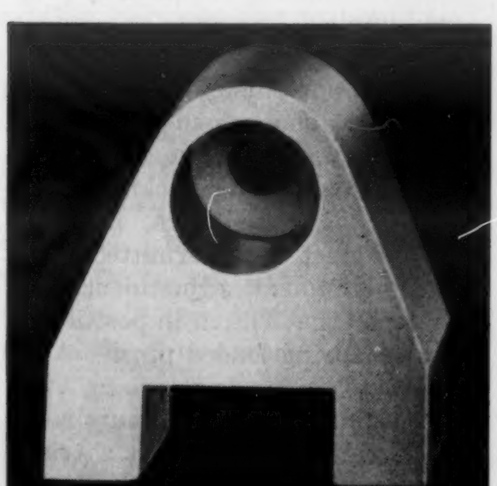
Porous gaskets *produced from type 316 stainless steel by gravity sintering have porosities of about 25%. Gravity sintering is also used in the production of filter media for handling corrosive solutions.*



Water meter gears *of type 302, pressed at 50 tsi and sintered at 2100 F, have 43,000-psi tensile strength, 15% elongation and 14% porosity.*



Rocker cams *are in production from 18:8 powder.*



Bearing seat *produced from type 310 stainless steel powder for service in high temperature applications.*

Stainless Steel Powder Parts

Prealloyed powders made by chemical method have good wear and strength properties and high corrosion resistance.

by Arthur Adler, *Alloy Metal Powders, Inc.*

■ To overcome machining difficulties with stainless steel, parts are now in production from prealloyed stainless steel powders using conventional powder metallurgy techniques. These parts retain the corrosion resistance of the steel and are in use as filters, instrument parts, bushings and gears, for service in corrosive environments and, in combination with Teflon powder, for floats.

The powder is produced by intergranular attack on the steels, which are subsequently broken down mechanically and screened. It is possible to control the grain size of the resulting material and powders can be produced which range from 100% plus 10 mesh to 100% minus 325 mesh including any percentage between these limits. Particles are irregular in shape although spheroidal powders in the same or equivalent size distributions can be produced.

The chemical composition of the finished powder is identical with that of the corresponding stainless steel in massive form and powders are in production in commercial quantities from types 302, 304, 316 and 310 stainless steels while other grades are also available now.

Because stainless steel is hard, carbide dies are recommended for parts production, especially where large quantities are to be fabricated. Lubricants are generally the same as those used for other metals, mainly stearic acid, stearates or waxes.

To prevent discoloration on the finished part, a highly reducing atmosphere is required for sintering. This atmosphere must be sufficiently dry to prevent moisture pick-up and contamination in the furnace. However, sintering stainless steel in a highly reduced atmosphere will tend to leave the part in an active state, thus making it susceptible to corrosion.

Passivation, which can be accomplished by immersing parts in a 6 to 10% solution of nitric acid at a temperature of 160 to 180 F for about ½ hr, then washing with water and drying, counteracts this action.

Porous media

Probably the first and still one of the most practical ways to produce stainless steel porous metal filters is through gravity sintering, i.e., sintering without pressing. The powder is placed in ceramic base trays and sintered in dissociated ammonia at temperatures between 2100 and 2300 F for periods up to 48 hr. The porous stainless sheets are subsequently rolled to produce better finishes and smoother surfaces, cut or punched and welded into various shapes.

In this method of filter manufacture, physical properties are controlled by the particle size distribution of the powder, the sintering temperature and time. In general, fine powder and long sintering time will produce components capable of filtering out particles as small as ½ micron, while coarse powders with short sintering times produce filters with mean pore openings of 65 microns or larger. The tensile

strengths of these gravity sintered filters range from 12,000 to 20,000 psi.

Stainless steel filters can also be produced by conventional methods involving pressing and sintering. The advantage of this is that any shape which is possible by the standard procedure can be duplicated in filter manufacture. The essential differerence from a structural part is increased porosity and permeability. Filter shapes require pressures of 1 and 5 tsi as contrasted with 30 to 50 tsi for parts requiring higher density. To improve porosity and permeability it is possible to use coarser powders or those having spherical shapes. Sintering times and temperatures are the same for both materials. However, tensile strengths would be comparable to filters made by the gravity sintering period.

Some present applications of gravity sintered stainless sheet are filters in coffee urns, laboratory type funnels, pipe insert disks, conventional type filters used in the chemical process industries, and biological filters.

The greatest potential use for gravity sintered sheet is in manufacture of de-icer and boundary layer control sheet for the aircraft industry. De-icing of an aircraft wing would be accomplished by forcing liquid through the porous sheet while in flight in order to keep the section free from ice formation. The boundary layer unit would increase lift and lessen drag for better efficiency. By sucking air through the porous stainless sheet on the leading wing edge, it is possible to control wind currents passing over the wing.

Stainless steel filters manufactured by conventional powder metallurgical methods are used in aircraft gasoline line filters, porous stainless steel bearings, and various types of oil, gas, and liquid filters. The corrosion resistant properties of stainless filters have been employed advantageously in filtering acids, alkalies and other corrosive solutions.

Structural parts

Physical and mechanical properties obtainable with stainless steel powders are a direct function of various combinations of compacting pressures, sintering temperatures and times and coining pressures.

Tests have shown that 150-mesh powder is about the most effective for parts fabrication. Typical analyses are given in a table. In general, it has been found that the distribution having the higher percentage of fines will give the higher tensile and elongation values. However the coarser size distribution requires lower compacting pressures with less dimensional changes.

Typical properties of compacts sintered in dry hydrogen are given in another table. It is apparent that, 1) effective sintering starts at 2100 F giving a tensile strength, without coining, of 29,000 psi, elongation of 9%, and 2) sintering at 2300 F followed by coining, produces maximum strength of 67,000 psi, elongation of 25%. Weight loss in hydrogen is 0.23 to 0.14 while dimensional change on sintering is usually less than 1%. Pressures of 30 tsi are sufficient for producing compacts of 302 or 316 for ordinary commercial use.

If a dissociated ammonia atmosphere is used in place of hydrogen the finished parts will have slightly higher tensile strength and somewhat reduced elongation. It is also possible to obtain hardness values higher than those shown in the table by increasing sintering time. The increased hardness is the result of nitriding the surface by dissociated ammonia.

Structural parts average 85% density in general. However, copper infiltration can be used for production of parts having maximum density if desired. Copper infiltration is accomplished by placing a slug of copper over the part before sintering. During sintering, the copper melts and flows into the compact filling the voids and producing full density. Silver infiltration can be used instead of copper to produce full density and improve

TYPICAL PROPERTIES OF STAINLESS STEEL POWDER PARTS

Compacting Pressure,[a] tons/in.^{2}	Coining Pressure,[c] tons/in.^{2}	Sint Temp,[b] F	Density			Ten Str, psi	Elong, % in 1 in.	Rockwell Hardness
			Green, gm/cm^3	Sintered, gm/cm^3	Coined, gm/cm^3			
30	—	2100	5.55	5.79	—	29,000	9.0	H-87
50	—	2100	6.04	6.32	—	42,500	14.0	B-40
50	50	2100	6.04	6.32	6.89	60,000	20.0	B-60
30	—	2200	5.55	5.79	—	31,000	10.0	H-89
50	—	2200	6.04	6.40	—	49,000	15.0	B-41
50	50	2200	6.04	6.40	6.89	63,000	21.0	B-60
30	—	2300	5.55	6.05	—	38,000	12.0	H-90
50	—	2300	6.04	6.60	—	53,000	16.0	B-42
50	50	2300	6.04	6.60	7.00	67,000	25.0	B-61

NOTES:
[a] *Compression ratio, average 1.88 to 1.00 using —150 mesh powder.*
[b] *Sintering time 1½ hr at temperature, atmosphere dry hydrogen, cooling rate ½ hr from sintering temperature to room temperature.*
[c] *Coined compacts annealed under conditions used for sintering.*
[d] *Porosity, average—based on 18-8 Stainless Steel density of 7.74 gm/cm^3—15.0%.*
[e] *Shrinkage, average dimensional change on sintering—0.80%.*

electrical conductivity as well. This broadens the use of stainless powder parts for electrical components.

Size and shape of the part determines the rate of production which varies from 200 and 1000 pieces per hr. As in the case of fabricating other metal powders, the complexity of the part determines the tolerance that can be held. Production tolerances of ±0.003 in. are general, ±0.001 in. can be maintained if required.

Among the first applications for stainless steel powder parts were small driving arms in water meters. The needs for higher resistance to wear and corrosion were paramount factors in determining the basic metal components. Stainless steel parts proved quite effective and at the same time reduced the cost per driving arm.

Drawn stainless tubing and bushings in industrial meters, used to measure highly corrosive liquids, are also being replaced by stainless powder parts. It has been suggested that the compacts resist seizure and have better wear qualities that those made from wrought or cast materials in bushing and gear applications because of the lower density and unique structure.

Among other applications are the fabrication of cigarette lighter cams, guides for fishing rods, small gears, levers and bushings. Stainless powder parts and porous media are in use in the automotive, aircraft, chemical process, food, pharmaceutical, marine and electronic industries.

Other uses

Recently there have been some developments toward combining metallic and non-metallic powders. Teflon powders, which can be fabricated by metal powder processes have been mixed with stainless powders to increase wear, strength and abrasion properties of the sintered Teflon. Since Teflon powders are sintered at about 800 F, the stainless powder is merely held in suspension within the component.

PROPERTIES OF PRE-ALLOYED 302 AND 316 STAINLESS STEEL POWDERS

Typical Screen Analyses			
Mesh Size		a	b
	+100 mesh	0.0	0.0
−100	+150	0.5	6.5
−150	+200	7.5	32.6
−200	+270	15.0	27.6
−270	+325	22.0	20.9
−325		55.0	12.7

Typical Powder Properties		
Property	a	b
Apparent Density, gm/cm³	3.41	3.50
Flow Rate, sec. (standard flowmeter 39.4 sec/50 g)	18.6	20.1
Weight Loss in Hydrogen (2100 F for ½ hr)	0.23	0.14

NOTES:
[a] *150 mesh—fine blend powder.*
[b] *150 mesh—coarse blend powder.*

Floats to be used in strong corrosive solutions offer an application for the combination of stainless and Teflon powders.

The processing of stainless steel flake, from stainless powder, has yielded an ideal pigment for metallic base paints and protective coatings. This flake, when mixed with a suitable vehicle, has provided a superior coating for various industrial and structural components which are subject to severely corrosive atmospheres. The coating of iron pipe with stainless steel paint has enhanced its value for transporting various types of corrosive agents. One outstanding property of this stainless steel coating is abrasion resistance.

Spray-welded coatings of industrial parts, where heat resistance is a desired property, are under development also.

Recent developments in magnetic clutches, where iron powders are used, have indicated that the ferritic chromium (magnetic) stainless powder surpasses iron in wear, strength and corrosion properties.

Shortages of stainless steel abroad have interested European steel manufacturers in the possibility of manufacturing stainless steel sheets from powder, because this steel could be made entirely from scrap.

Design and cost

The desirable properties of the powder and the attainable savings in fabrication cost have stimulated interest, not only in the industries that are presently using metal powder parts, but among engineers and manufacturers having machining problems with stainless steel.

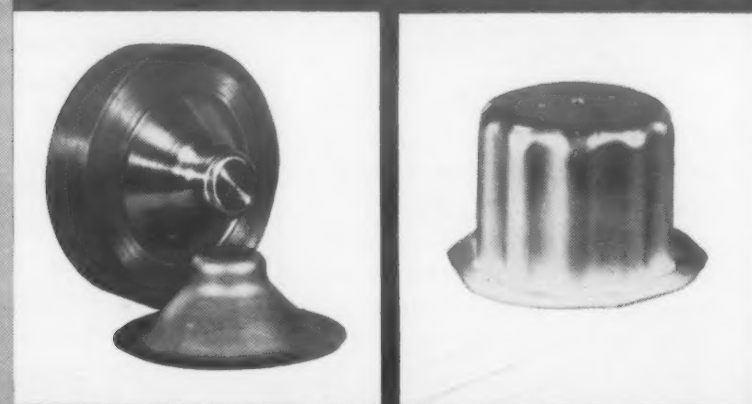
The price of the powder today is higher than that of bar or sheet stock, but the savings achieved through metal powder processing offset this disadvantage. Actually, the cost of a stainless powder part, in most cases, is lower than a machined part; in all cases, where the part can be produced from powder, it is competitive with machining.

As in the case of many newly developed materials, cost is high, because of low rates of production and consumption. Price reduction can be expected when consumption increases and full advantage is taken of productive capacity. As in fabrication of other metal powders, die cost is an important factor. Production quantities must be large enough to make stainless steel powder parts competitive with other forms of stainless fabrication.

Generally, design limitations for stainless parts conform with those of iron powder parts. Higher compacting and coining pressures are required however. Type 302 and 316 alloys can be compacted under 30-ton pressures effectively but 40 to 50-ton pressures are required for the higher nickel chromium stainless steels such as type 308, 309 and 310. The increased pressure reduces the size of part that can be handled in a given capacity press and places limitations on the fabricator.

Rubber Press Pad

Flexible Female Die



Flexible Male Die

Drop Hammer

Short Run Press-Formed Parts

MATERIALS & METHODS MANUAL No. 114

This is another in a series of comprehensive articles on engineering materials and their processing. Each is complete in itself. These special sections provide the reader with useful data on characteristics of materials or fabricated parts and on their processing and applications.

MARCH, 1955

by Malcolm W. Riley, *Associate Editor, Materials & Methods*

Some new, some old, these press developments are intended to adapt the mass production press to the economical forming of relatively small quantities of sheet metal parts. Though widely used in the aircraft industry in the past, they are gradually finding increased useage in the manufacture of consumer goods.

The purpose of this manual is to tell you what the methods are, the kind of parts they can form, and to aid you in designing for short run production. The four forming methods are discussed in light of:

- Forming Principles
- Advantages and Limitations
- Materials Formed
- Design Considerations

What is a Stamping?

As the metal working field has increased in complexity, so has the confusing terminology. For some people, certain metal-working terms have taken on meanings which may or may not coincide with the connotations assumed by others. For example, there are innumerable criteria used to define the term "stampings." To some segments of the metal-forming industry stampings are limited to sheet metal parts formed on a punch press. To others they include parts or components formed under pressure from a variety of forms of metal.

Other definitions are based on the type of metal forming involved. For example, a stamping is a part which is predominantly blanked, formed and pierced, with perhaps a slight draw, while a deep drawn part would fall in a separate category. Another definition involves the quantity and size of the part.

Whatever definition is accepted, it is evident that there is a need for standardization of terms. Terminology, to some, might appear unimportant, but words are the only way in which ideas can be exchanged. The Pressed Metal Institute has already inaugurated a program which will include the clarification and standardization of definitions for various terms used in the pressed metal industry. It would seem that an organization of this type would provide an ideal meeting ground for the various segments of industry to discuss and resolve a problem which, if unsettled, can only lead to misunderstanding and confusion.

■ Sheet metal parts formed or drawn on a press are usually produced in large quantities, since a hydraulic or mechanical press is basically a long run production machine. However, in recent years there have been a number of developments in press operations whose purpose has been to adapt the mass production press to economical sheet metal forming over a relatively short production run. Essentially the developments allow reduction of tooling costs to a degree which permits their amortization over a smaller quantity of parts.

Of the press forming developments discussed here, some are relatively new, others are older, but as yet have not been fully exploited. Developments fall in two general categories: 1) substitution of a flexible die medium for one die member; 2) substitution of tooling materials, the characteristics of which allow substantial reduction in tool fabrication costs.

Flexible die forming

The flexible die methods to be covered are:

Rubber pad or Guerin process—A rubber block or pad in the head of the press is used as the second die member to form a sheet metal blank around a punch or form block. Because there is no hold-down action on the blank, the predominating shapes are flanged and formed parts with some slight drawing possible with auxiliary fixtures.

Flexible female die—Two methods are described, one typified by the Hydroform press which uses a flexible diaphragm covering a cavity filled with hydraulic fluid. Pressure is exerted on the diaphragm by the fluid, and when the punch moves into the rubber, the fluid exerts forming pressure. The other method, the Marform press, utilizes a solid rubber pad which holds the blank, while regulated hydraulic pressure allows the punch to move into the pad, forming the part. In both cases, because the flexible die medium exerts hold-down pressure on the blank, prior to, and during forming, sheet metal shapes are predominantly deep drawn, though both presses can be adapted to simple flanging and forming operations.

Flexible punch—Water or soluble oil is used as the male die member to force the sheet metal to conform to the configuration of the female die. Predominant shapes are embossings, shallow drawings and cone-shaped parts.

All the flexible die press-forming methods offer certain common advantages and limitations. The major advantages are:

1. Reduction in tooling cost—Tool cost is reduced since only one die member is required, the universal flexible medium being substituted for the second member of the die set. Not only is the number of tools reduced, but the costly matching of two die members is eliminated. The cost reduction will generally run about 30 to 80% depending on the part, though larger reductions have been effected.

2. Reduction in lead and set-up time—Since only one half of the conventional tooling is required, tool fabrication time is greatly reduced, permitting a shorter lapse between design and production. Reduced fabrication time is, of course, reflected in the overall tool cost reduction. Auxiliary fixtures and tools used to aid forming are generally standardized and stocked.

The reduction in tool set-up time resulting from elimination of the second die member is particularly important from the standpoint of flexibility of operations. In many companies and job shops, production orders are received piecemeal and the total quantity of parts is not known at the outset. The flexibility afforded by a short tool set-up time can be of great advantage in that a shop can shift production from one type of part to another with a minimum lapse of time and at low cost.

3. Minimum tool wear—Use of flexible die members minimize wear on the punch.

4. No die marks — Whether the flexible die member consists of rubber or fluid, it will leave no die marks on the side of the part with which it is in contact.

5. No tooling change when changing gage of material—A flexible punch or die is universal in that when a change is made in the gage of material being formed, the tooling does not normally have to be changed. The only adjustment made is in forming pressure. Conventional matched dies are mated to allow clearance for the specific thickness of sheet metal being formed. When the thickness is altered, the tools must be changed.

The major limitations are:

1. Pressures—The major restriction on parts that can be formed by flexible die methods lies in the limited capacity of presses available.

2. Shapes—Each type of press discussed has limitations on the design and shapes of the parts it can form. These will be discussed in more detail in the ensuing sections on design considerations.

Drop hammer forming

The second category, low cost tooling materials, covers drop hammer work. Zinc base alloys and lead are normally used for the dies since their low melting points permit rapid and economical fabrication of tools. Because there is relatively little hold-down force exerted on the blank, parts formed by a drop hammer are predominantly formed shapes, though relatively deep drawing can be accomplished through the aid of auxiliary tooling. Actually there are few limitations on the types of parts which can be produced with a drop hammer. Operating a hammer is an art, and the skilled operator can produce almost any shape by judicious use of the machine. It is mainly used for development of part design and tooling.

The general subject of low cost tooling materials is one that would require a great deal more space than is available here. It is

What is Short Run Production?

The term "short run production" is a relative term meaning different things to different segments of the sheet metal industry. When small parts, such as fasteners are being stamped out on a punch press, quantities up to 10,000 parts would most likely be considered a short run. The aircraft industry, on the other hand, generally deals with sheet metal parts in quantities ranging from developmental lots up to several hundred. A quantity of parts sufficient for a thousand planes or more would definitely be considered long run and are not often encountered.

Sheet metal parts for consumer goods may fall in any of several categories. Automotive panels may be turned out in "short run" quantities of 25,000, or in long run quantities of a million or more. Or components for some consumer goods may be produced in quantities of only several hundred to a thousand or so before design change becomes mandatory for competitive reasons.

Thus, it would be impossible to set definite limitations as to short or long run production. For the purposes of this manual, however, the parts to be discussed are relatively large, drawn or formed sheet metal parts produced in "short run" quantities ranging from developmental lot sizes to several hundred or a thousand. Since all the press developments discussed here, with the exception of drop hammers, apply mainly to hydraulic presses, production rates are relatively low in comparison to parts produced with progressive dies on punch presses.

Bending, Forming and Drawing

Since some confusion exists as to terminology used for sheet metal forming, this section is devoted to describing some types of forming operations and the general degree of plastic deformation involved.

In cold working, when a sheet metal is deformed to such an extent that it will not regain its original shape when released, some degree of plastic deformation has occurred. That is, the stresses in some areas of the sheet have exceeded the elastic limit of the material. A simple bend produces the minimum plastic deformation, while deep drawing is the extreme case. Between the two extremes infinite degrees of plastic deformation occur, depending on the shape produced.

Three basic categories of deformation can be illustrated by 1) the simple bend, with the minimum of plastic flow, 2) the curved bend, where the metal must be stretched or shrunk around the contour of the curve, as well as in the bend itself, and 3) a drawn cup, where the shape is formed by controlling the plastic flow over most of the area of the sheet. Bending and forming predominantly involve deflecting the sheet material until it follows the contour of the punch or form block, while drawing involves stretching the sheet and wrapping it around the punch while the material is in the plastic range.

The ultimate degree to which sheet metals can be formed or drawn is dependent mainly on the materials themselves, their thickness and the geometry of the part. The press developments discussed in this manual do not alter the ultimate properties of the sheet materials. They do provide different controls over the metal-forming which result in certain limitations and advantages which must be understood in order to use the methods effectively. Therefore, design factors discussed are limited mainly to those which differ from factors applying to conventional sheet metal press work.

difficult to make generalizations about it. Low cost tool materials include zinc-base alloys, aluminum, antimonial lead, bismuth-base alloys, hard wood, reconstituted wood, densified wood and plastics. Plastics in particular are currently of tremendous interest to the sheet metal industry. They are easily formed at room temperature, and possess adequate physical properties for developmental or short run production of many types of sheet metal parts.

The primary advantage of all these die materials is their ease of forming, i.e., either low melting points which allow the dies to be formed against plaster or against the other die member, or ease of machining which permits economies in finish-forming the die to the desired shape. Low cost die materials are used in many combinations, and the economies inherent in die fabrication must be balanced against their physical properties, in light of the configuration of the part and quantity of production. Where applicable, the use of low cost die materials will be discussed in conjunction with forming methods in each of the sections on the following pages.

Forming with Rubber Pads

Rubber pad forming, sometimes called the Guerin Process or hydropressing, involves substitution of a rubber pad or block for the female die. The rubber pad is contained in the head of the press, and in effect, forms the upper platen. A properly contoured form block is placed on a bolster on the bed of the press, the sheet metal blank is placed on the form block, and the press is closed. By thus forcing the form block and blank into the rubber pad the part is formed to the shape of the block. Rubber, like water, is virtually incompressible. By properly containing it within the metal box and the bolster, pressure is built up in all directions to equal the pressure exerted by the press ram, thus forming the sheet metal to the desired shape.

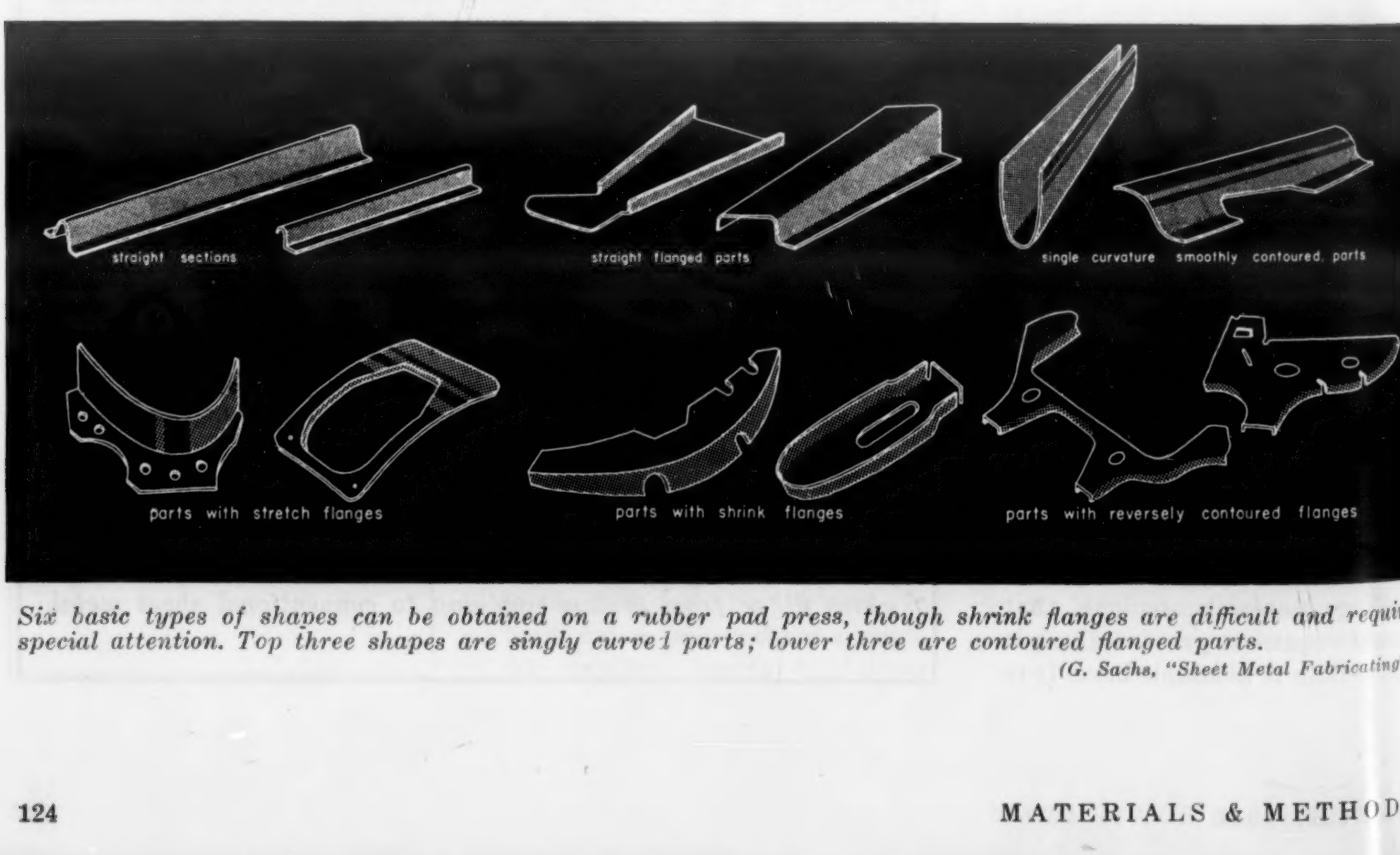
The effective psi forming pressure exerted on the part can be determined by dividing the press capacity (in lb) by the area of the rubber pad (in sq in.). Thus, on a press of any given capacity, the forming pressure can be regulated by altering the size of the rubber pad. By substituting a pad of smaller area, a substantial increase in forming pressure can be obtained. Usual forming pressures range from 1100 to 1500 psi, though presses equipped with smaller pads yield up to 3000 psi.

Types of shapes

Rubber pad forming is suitable for most types of simple bending and forming of sheet metals. It is not adaptable to deep drawing operations for there are no draw rings or pads to exert sufficient hold-down forces. With the aid of auxiliary fixtures and tools relatively shallow draws can be formed in some cases. The rubber pad press is generally used to replace some matched die, press brake and hand forming operations. It can be used to form straight flanges, stretch and shrink flanges, beads, corrugations, or embossing and can accomplish some trim, and pierce operations.

Equipment and tools

Though both hydraulic and mechanical presses can be used with the trapped rubber head, the hydraulic is more commonly used. The mechanical press has an inflexible limitation on length of stroke, whereas the hydraulic press automatically closes to the point of maximum press capacity. Obvious advantages in press set-up time incur from the use of the hydraulic press in that



Six basic types of shapes can be obtained on a rubber pad press, though shrink flanges are difficult and require special attention. Top three shapes are singly curved parts; lower three are contoured flanged parts.

(G. Sachs, "Sheet Metal Fabricating")

should a small form block be substituted for a large one, no additional bolster or press regulation is required to gain full advantage of the depth of rubber available.

The rubber pad may be solid or in the form of laminates, a durometer hardness range of 30 to 90 being used. The harder forms provide better shearing and punching action while those of intermediate hardness are better for forming. Most commonly used pads range from 55 to 70 durometer.

In rubber pad forming, the form block, which corresponds to the punch in matched die forming, can be made of various materials, depending on the configuration of the part, production quantity and the severity of subsequent finishing operations. Boiler plate or cold rolled steel can be used where relatively long runs are necessary, or hand hammering is required to finish-form the part. When forming sheet aluminum or Kirksite, aluminum form blocks may serve for shorter production runs. Where there is no localized build-up of pressure on the part, such plastics as Micarta, Masonite or some of the tooling resins may provide sufficient tool life.

When the sheet metal is strong and the angle to be formed large, the rubber pressure alone may not be sufficient to provide clear definition of shape. To guide and direct the forming pressure, numerous auxiliary tools have been developed. The most common tool is the cover plate which is usually of steel and is placed on top of the blank and form block to prevent tipping or deformation of the web area during forming. A reaction block in the form of a wedge may be placed so as to trap the rubber between the wedge and the flange of a sharp angle which is being formed. Further increases in localized pressure may be obtained by adding a draw bar or roller bar or wedge between the reaction block and the metal to mechanically force the metal to contour. A wiping plate may be hinged to the bolster, and the unhinged side placed on top of the blank edge before closing the press. When the rubber encounters the wiping plate, the plate "wipes" the edge of the blank down to form the flange or bend desired.

Other tools used extensively are rubber pressure pads. The pads are of varying thicknesses and are laid over localized areas of the part where additional forming pressures are required. In effect, they provide a greater mass of rubber, thus greater pressures at those critical areas.

Advantages

The advantages common to all flexible die forming methods apply to rubber pad forming. There are certain additional advantages which should be noted.

Multiple forming—The number of parts which can be formed with one press stroke is limited only by the size and shape of the bolster and the parts. Generally, several parts can be placed on the bolster at a time, as long as sufficient room is left between the form blocks to accommodate the rubber pad when the press is closed. Parts can be formed rapidly since most rubber pad presses have movable reciprocal tables so that one load of formed parts can be removed and new blanks positioned while the press is forming a group of parts on the other end of the table.

Undercut shapes—Due to the flow of the rubber undercut shapes can be formed to a degree, whereas in conventional press forming, multiple stage or double-acting dies would be required.

No down-time—Since form blocks are merely placed on bolster prior to blank-forming, the press need not be stopped for a change of tooling.

Limitations

Subsequent operations — Depending on individual configuration, sheet material used and degree of accuracy required, subsequent hand-finishing of parts may be required. One aircraft company reports that working to tolerances of ± 0.5 deg on basic contour lines, ± 2 deg on stiffener flanges and +0.010, −0.000 on joggle depths, roughly 80% of their rubber pad-formed parts require some degree of hand-forming. It should be pointed out that these are government specifications for a precision aircraft. Under normal requirements of components for consumer goods a great many parts can be formed with no hand-finishing at all.

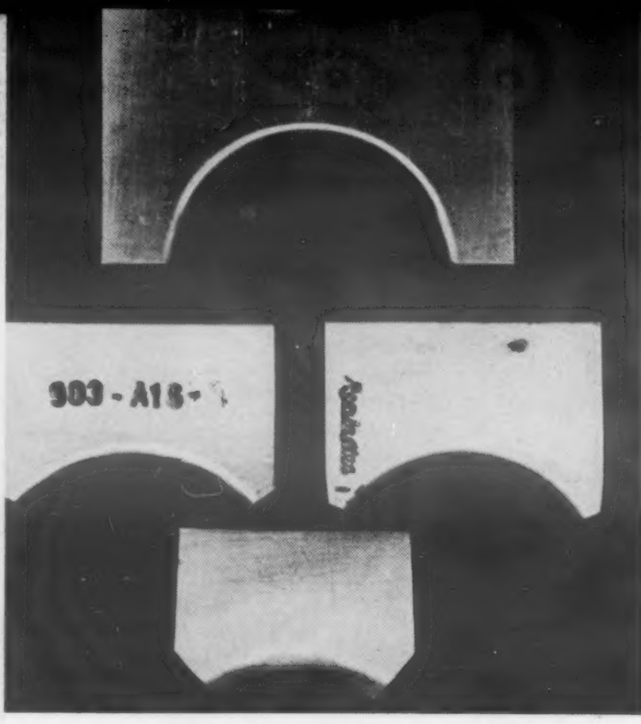
Typical aluminum parts *formed by the rubber pad press method. They contain straight flanges, stretch flanges, shallow-contoured shrink flanges, beads and flanged lightening holes.*

(Reynolds Metals Co.)

Sheet materials

Metals commonly formed by rubber pad presses include the heat-treatable aluminum alloys, austenitic stainless steels, and to a lesser degree, magnesium and titanium. From the standpoint of forming characteristics, materials should be formed in their softest condition. However, if subsequent heat treatment is necessary, distortion could be such that substantial hand-finishing might be necessary. Therefore, where possible, aluminum alloys should be formed in the —T condition.

Where distortion due to subsequent heat treatment poses a major problem, 2024, 7075 and 6061 may be formed in the as-quenched condition. At that stage the ductility of aluminum



Stretch flanges *in 0.030-in. RC-130 titanium sheet were formed on a rubber pad press with a forming pressure of 3200 psi. Flange height is 0.500 in.*

(Chance-Vought Aircraft, Inc.)

alloys lies somewhere between that of—O and —T3 conditions. Care should be taken when forming in the as-quenched condition since the ease of forming will depend on the extent of room temperature aging which has occurred. As-quenched, 2024 remains reasonably soft for about 20 min, while 7075 remains soft for about 2 hr. Refrigerating at 0 deg F will keep parts soft for approximately one week. In the majority of applications, however, aluminum alloys are formed in the —O condition since in that state they are the most ductile and easiest to form.

Annealed austenitic stainless steels can be formed quite readily by the rubber pad method due to their high elongation characteristics. Stretching and bending characteristics are relatively good, though shrinkage is limited in the thin gages in which they are used. The aircraft steels, 4130 and 8630, can be formed with a fair degree of success in the annealed condition. Quenching distortion in flat areas can be minimized by clamping during tempering.

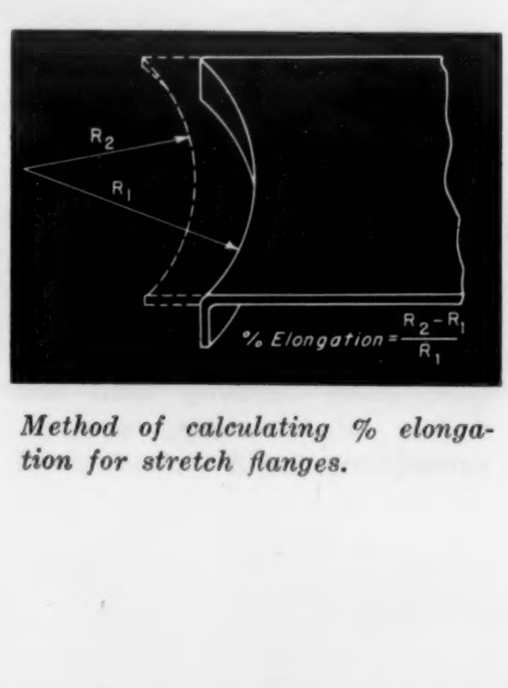
Though magnesium and titanium can be formed cold to some degree, hot forming is recommended. Metals can be formed hot on a rubber pad press, but it raises the cost of the operation and cancels some of the advantages of the process. Facilities for heating blanks must be available near the press and a throw blanket of high temperature rubber or a similar material must be placed over the hot blank to protect the press pad.

Though annealed FS1-A magnesium can be formed with relative ease at room temperature, heating it to around 600 F is recommended to reduce spring-back and for severe forming operations. Hard rolled FS1-H should be formed at around 300 F for optimum results. RC-70 titanium alloy has been formed with the rubber pad press at temperatures of 700-800 F. Steel form blocks are recommended and if subsequent hand-work is required, torch heating should be applied.

Design condsiderations

Flanges—Flanges are probably the most commonly encountered contour in rubber pad formed parts. Bend radii, spring-back allowances and bend allowances are roughly the same as in die forming. In fabricating the form block, the spring-back for the specific flange should be calculated and allowed for in the form block radius. To improve the accuracy of large angle bends in heavy, strong metals, reaction blocks, wedges and wiping blocks can be used to provide additional localized forming pressures.

Straight flanges are simplest to form, the only calculations required being minimum width of flange and allowance for spring-back. Stretch flanges, where the flange contour is concave, can be readily formed, though auxiliary fixtures are usually used in order to provide higher localized pressures.



Method of calculating % elongation for stretch flanges.

Design limitations on rubber-forming stretch flanges are generally the same as those for die forming. They will depend on the material being formed, the flange width, radius of the flange and radius of the curve. To relieve stresses in the metal, cut-outs, scallops and flutes may be used, except that to prevent cracking in hard materials, such as 2024-T, cut-outs cannot extend into the web without cup reinforcing.

Web areas of sheet metal parts often have lightening holes to reduce weight. By flanging these holes, the advantage of weight reduction is coupled with increased strength due to the flange. On a rubber pad press external flanges can be formed around lightening holes more readily since the rubber pressure is acting over the entire area of the web. In forming internal flanges, the rubber pressure acts on the flange area alone. A 60-deg flange angle is commonly used in flanging lightening holes.

Shrink flanges, where the flange contour is convex and the metal must be shrunk during forming, generally cannot be formed on a rubber pad press without subsequent hand-finishing. The metal tends to buckle and the rubber cannot perform the ironing action provided by matched dies. Degree of buckling will depend on geometric factors and properties of the metal used. Buckling generally increases with decreasing metal thickness, decreasing contour radius and increasing flange width. Sheet metals with high yield strengths, low elastic moduli and low strain-hardening capacities are more liable to wrinkle than those with reverse properties. The metal should be soft, and the flange thick and narrow rather than wide and thin. As a general rule, flange widths should not exceed 3 or 4 times the metal thickness. Auxiliary tools such as wiping plates or reaction blocks can be used to

RECOMMENDED LIMITATIONS FOR RUBBER PAD FORMING

	Heat Treatable Aluminum Alloys		Austenitic Stainless Steels	
	O-Condition	T-Condition	Annealed	¼ Hard
Max Sheet Thickness, in.	0.187	0.064	0.078	0.032
Recommended Flange Width (straight flanges, not over 90 deg), in.	$\frac{1}{16} + 2.5\ T^a$	$\frac{1}{8} + 4\ T^a$	$\frac{3}{16} + 4.5\ T^a$	⅝
Max Metal Thickness for Forming Stretch Flanges, in.	0.125	Special Methods Required	0.050	0.016–0.030
Max Metal Thickness for Forming Lightening Hole Flanges, in.	0.125	0.064	External 0.060 Internal 0.050	External 0.040 Internal 0.030

[a] *T = Metal Thickness.*

bring actual metal shrinkage up to around 10% in annealed alloys.

The draw clip is another tool used to eliminate buckling during forming of shrink flanges. It consists of three sheets of metal joined together in a sandwich fashion. The center "spacer" sheet is formed to the contour of the shrink flange and the bottom sheet is shaped to the contour of the form block. After the blank is positioned on the form block, the clip is slipped over the blank edge at the point where the shrink flange is to be formed. As the ram descends and the rubber envelops the form block, the clip keeps the flange edge from buckling as it is formed, and disengages from the flange after forming.

There are various design techniques which minimize or eliminate wrinkling of flanges. Flutes, scallops and cut-outs when used judiciously may help to provide a smooth flange. Flutes, or controlled wrinkles, provide a stretching action rather than shrinking the metal in the flange and are preferable to scallops or cut-outs where possible. They permit sharply contoured, convex flanges in materials such as 2024-T and ¼-hard stainless steels as well as in softer materials.

In effect, cut-outs reduce the length of the flange so that actual shrinkage is kept below the small shrink limits of the materials. Corner cut-outs are also used to relieve high stresses which would otherwise be set up in a sharp shrink flange.

Reverse-contour and joggle flanges—A reverse-contour flange is one in which both stretch (concave) and shrink (convex) flange areas are incorporated in a single flanged edge. A joggle is merely a reverse-contour flange compressed so that the stretch and shrink areas are in close proximity. When the curved sections of joggled flanges are relatively short in relation to flange width, there is a pronounced reduction in the strains at the flange edge. If the flanged edge is very short, the stretch and shrink may compensate each other to a large degree, particularly if the metal is soft. Most of the stress reduction due to this reciprocity will be gained in the stretch-flange area, while wrinkling may still occur in the shrink-flange area.

On the other hand, if the curved areas of a reverse-contour flange are long in relation to flange width, a reversal of contour has little effect on the strains in the flanged edge. The compensation effect of reverse-contour flanges is a complex phenomenon which may cause considerable distortion if the curvature radii are small and the metal hard. To minimize distortion, joggles or offsets are usually formed with the assistance of auxiliary tooling of the type used to form plain shrink flanges.

In calculating dimensions of joggles which can be formed in various sheet metals, the relationship between joggle allowance and joggle depth is a basic factor. The joggle allowance is the length of the offset edge including the contoured flange portions. In soft aluminum alloys, joggle allowance should generally be at least 4 times joggle depth. It should be greater for the harder alloys and should increase with increasing metal thickness. Sheet in thicknesses greater than 0.070 in. are usually joggled with the aid of a beveled and notched form block which minimizes surplus length along the flange edge.

In annealed stainless steels, joggle allowances should generally be at least 6 times joggle depth, maximum sheet thickness that can be joggled is around 0.050 in., and the maximum joggle depth is around ¼ in. Joggles can be formed in ¼-hard stainless in thicknesses up to 0.050 in., and to a depth up to 3/32 in. The joggle depth can be increased to 3/16 in. if the part is to be hand-finished.

Beading—Beading, which may be required for integral stiffening, decoration, or to meet other design specifications, can also be formed on a rubber pad press. The depth of bead will depend on the metal being formed and the method by which it is formed. Much deeper beads can be made by external beading than by internal, since in the former, the rubber exerts pressure on the entire web rather than on just the bead area. In many cases, however, external beads cannot be used as they destroy the flat area of the web.

External beads in softer metals, such as annealed or as-quenched aluminum alloys, may be formed to a depth of ⅛ to ⅝ in. Ratio of width to depth of bead should not exceed 0.25 for wide beads in thin metal, and 0.08 for narrow beads in thick metals. Bead width is measured by the flat-to-flat distance between the outer bend lines. Length of bead should exceed 2½ times its width, and

parallel beads should not be spaced closer than a distance between their center lines equal to 8 times their depth. Minimum distance from a free edge will range between 2 and 6 in., and from a flanged edge will range from 1 to 5 in., depending on bead depth. The distance from the end of a bead to an edge should be at least 2 or 3 times bead depth or $\frac{1}{4}$ to 2 in.

Internal beads in the softer metals may be $\frac{1}{8}$ to $\frac{3}{8}$ in. deep, and depth-to-width ratio should generally not exceed 0.16 to 0.20 for all sheet metal thicknesses. Bead width should not be less than 16 times the metal thickness, and $\frac{1}{8}$ in. is recommended for the edge radius of the bead. Parallel beads can be spaced closely together and beads parallel to edges should be kept at least $\frac{1}{2}$ in. from the edge. Internal beads perpendicular to an edge may come up to the bend line of a flange or very close to an edge. Isolated beads in aluminum alloys in the —T condition are hard to form without severe "oil can" distortion.

In annealed austenitic stainless steels half-round beads with a depth-to-width ratio of nearly 0.5 can be formed by either the internal or external method. However, the thickness of metal will have a large effect on the degree of distortion. In very thin sheets, wrinkles may develop at the ends of external beads. Internal beads can be formed in sheet metal thicknesses up to 0.050 in. Where beads must be formed relatively close to the edge of the part, a rough blank should be used since there is more metal available to be drawn into the bead. In $\frac{1}{4}$-hard stainless steel, single beads cannot be formed without excessive canning distortion.

Internal beads in flanges can be formed to a depth-width ratio of about 0.2; however, they must be contoured more smoothly than those formed by matched dies. External beads in flanges can be made deeper by forming them in a first operation on an undeveloped blank. When corrugating or embossing is involved, depth of bead in the harder materials can approach more nearly that of beads in softer metals, since corrugations in a web reduce the amount of canning distortion.

Trimming and Punching—The rubber pad press may be used for some trimming and punching operations, but it is not done extensively, since the sharp cutting edge or piercing button gouges the rubber after penetrating the blank. Normally a rubber throw pad is used to protect the forming rubber in the press head.

Variations of rubber forming

Variations on the basic rubber pad press involve various methods of increasing the forming pressures. As was mentioned before, some operators have increased the pressure by reducing the area of the rubber pad to gain forming pressures up to around 3000 psi. Another approach adds hydraulic pressure to that applied by the solid rubber pad to gain pressures of 5000 to 7500 psi, coupled with economies in plant space, press weight and press cost.

The Verson-Wheelon hydraulic press uses a 35 to 40 durometer neoprene work pad backed with an inflatable bag. The bed of the press consists of a movable table, one end of which can be loaded and unloaded while the other end with a load of parts is in the press. When the loaded table is under the pad the bag is inflated with hydraulic fluid, displacing the work pad down over the work. In effect the hydraulic fluid provides pressure to the rubber pad which forms parts.

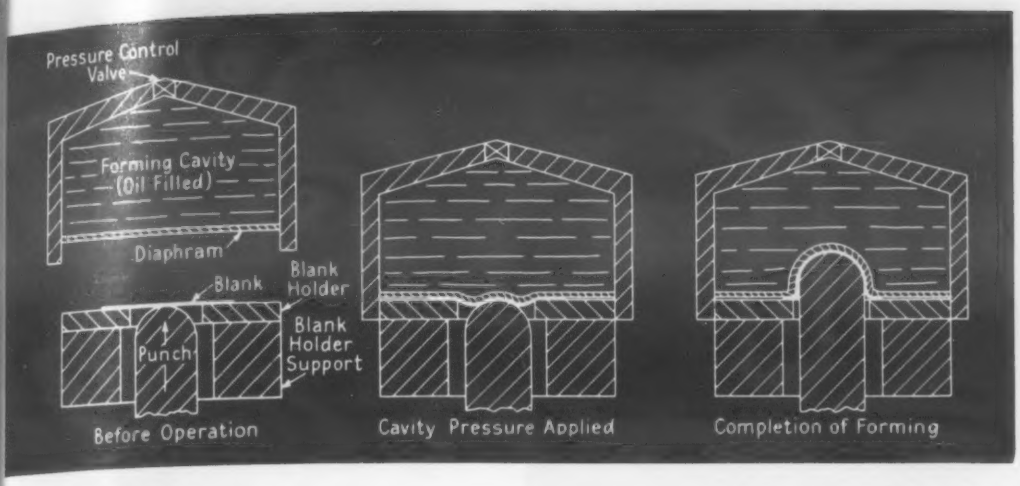
The forming principle is basically the same as that of the plain rubber pad press and the same types of parts are formed. Specifications for design configurations are roughly the same though the increased pressure produces deeper flanges in heavier sheet material than is possible with rubber pads alone. The higher pressures generally provide clearer definitions of configurations. Shrink and "C" flanges can be formed in heavier gage materials and the pressures provide somewhat of an ironing effect which helps to minimize wrinkling. In the lighter gages where buckling cannot be eliminated the higher pressures are disadvantageous in that hand-finishing is more difficult.

When working with higher forming pressures, more stable tooling materials should be used. Steel, aluminum or Kirksite are generally employed, though for some types of shapes, plastics or wood may suffice. With the improved forming inherent in higher forming pressures, need for auxiliary tooling is reduced to a minimum. The most commonly used devices are rubber or leather throw pads which minimize wear on the relatively soft work pad and provide localized increases in pressure.

Deep Drawing With Flexible Female Dies

There are several press developments aimed at combining the economic advantages of the rubber pad or Guerin process with the forming advantages of matched metal draw dies. The developments involve substituting a flexible female die medium which provides a hold-down action while the part is formed. The hold-down action permits deep draws to be made economically and provides additional advantages over conventional drawing practice.

Rubber pad forming is not well suited to drawing metal or forming metal where metal shrinkage



Hydroforming Cycle *(International Nickel Co.)*

is involved because the initial stages of forming are carried out with little pressure on the blank. Since no hold-down pressure is exerted on the blank flanges during forming, the metal tends to wrinkle and buckle in shrink areas as discussed above. The pressure exerted by the flexible female die provides sufficient force to prevent the blank from wrinkling and buckling and allows relatively deep draws. The pressures and speed of forming are regulated by hydraulic fluid.

There are two basic types of presses which will be described to illustrate the forming principle. The Hydroform machine, produced by the Cincinnati Milling Machine Co., and the Marform Press, developed by Glenn L. Martin Co., and produced by Loewy-Hydropress. A brief description of the forming principles of the two machines will make clear the advantages and limitations of each method.

Hydroforming

When the machine is open, the ram with the solid male punch is retracted so that the top of the punch is flush with the metal draw ring. The blank is laid on the draw ring and in the first operation the press is closed with the rubber diaphragm in the press head in contact with the blank. Hydraulic fluid is then pumped into the cavity behind the diaphragm to hold the blank firmly in place on the draw ring. Pre-pressure can be applied up to about 8000 psi according to the type of sheet material, the gage and the configuration of the part. The prepressure holds the blank against the draw ring, eliminating wrinkling during drawing. The final step of the cycle forms the draw by forcing the punch and blank up into the diaphragm and hydraulic cavity. The hydraulic pressure is built up equally on all sides of the cavity and over the entire area of the blank, forming it to the configuration of the punch. The maximum effective forming pressure developed is 15,000 psi.

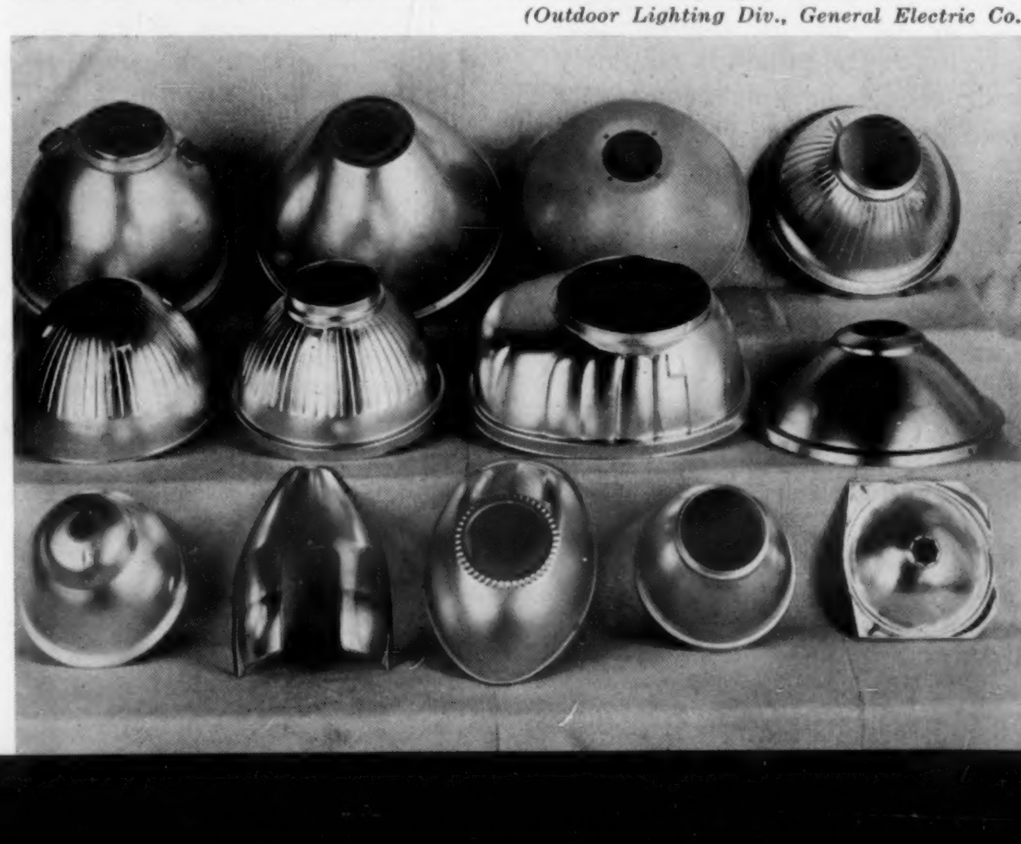
Equipment and Tools—Hydroform machines are available in a variety of sizes, the size designation referring to the diameter of the flexible diaphragm. Since the entire area of the diaphragm may be used for forming, the diaphragm size dictates the maximum sized blank. At present, presses are available in 8, 12, 19, 23, 26, and 32-in. diameters with maximum draw depths ranging from 5 in. for the smallest press to 12 in. for the largest. Maximum forming pressures obtained with maximum hydraulic pressure and punch extended, is 10,000 to 15,000 psi depending on the size of the machine. Maximum rate of operation ranges from 200 cycles per hr for the smallest to 90 cycles per hr for the largest.

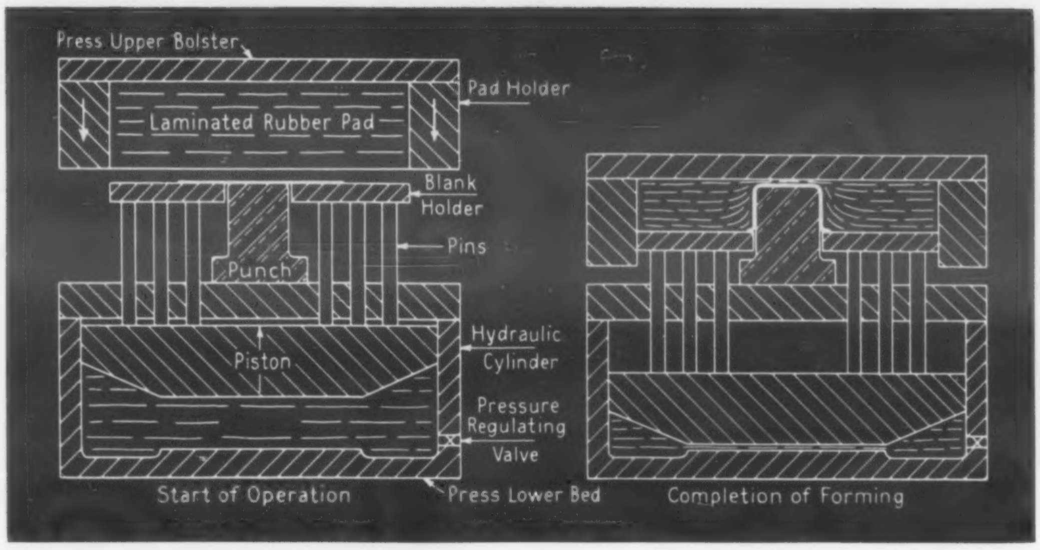
The only tooling required for Hydroforming is a draw ring and a punch of the desired shape. The punch and ring must be so fitted that the punch will move easily through the ring. Normal clearance allowed between punch and ring is 50% of the sheet metal thickness. Punches may be made of steel or, where interior surface finish on the part is not critical, cast iron. For shorter production runs Kirksite, hard wood, brass, aluminum or plastics may provide additional economies.

Marforming

The head of the Marform press contains a rubber pad similar to that used in the Guerin press. The punch is mounted at a fixed elevation in the press bed. Surrounding it, and flush with the top of the punch at the beginning of the forming cycle, is a blank holder mounted on pressure pins, which in turn rest on a piston. The piston is supported by hydraulic fluid in a cavity below. The blank is laid on the blank holder and punch, and the press is closed bringing the rubber pad in contact with the blank. As

Aluminum parts *Hydroformed in thicknesses ranging from 0.040 to ⅛ in.*
(Outdoor Lighting Div., General Electric Co.)





Marforming Cycle *(International Nickel Co.)*

the press head descends, a cam actuator device regulates the release of hydraulic fluid from behind the piston, lowering the blank holder and allowing the punch to form the blank as it forces it into the rubber pad. The rubber pad exerts holding pressure on the blank flange, preventing wrinkling as the sheet is drawn over the punch.

Equipment and Tools—Marform presses are produced in various sizes. Onc, which has a forming area of 16 x 18 in. provides a forming pressure of 5560 psi, while a unit with a 28 x 31-in. forming area provides forming pressures of up to 8000 psi. Forming pressures of 6000 to 7000 psi are commonly used. Speed of operation ranges from 60 to 240 cycles per hr.

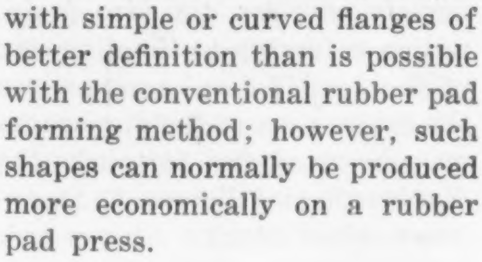
Tooling requirements are similar to those of Hydroform. Only a blank holder and punch are necessary, fitted to allow suitable clearance for easy movement of the blank holder down over the punch. Choice of tooling materials for the punch is similarly wide. Steel is most commonly used for longer production runs, while for shorter runs, dependent on the configuration and the material being formed, Kirksite, hard wood, brass, aluminum or plastics may provide additional economies.

Types of shapes

Since the flexible media of both methods exert a hold-down force on the blank, deep drawn shapes predominate. They may be in the form of flanged cups, spherical domes, or rectangular and square recessed shapes. The forming methods are particularly economical for drawing unsymmetrical shapes with embossed or recessed areas. They can be used for forming "C" flanges or, with segmented punches, for drawing shapes with open ends smaller than the closed. With proper tooling set-up they can also be used for forming shapes with simple or curved flanges of better definition than is possible with the conventional rubber pad forming method; however, such shapes can normally be produced more economically on a rubber pad press.

Advantages

The advantages common to all flexible die forming methods apply to Hydroforming and Marforming. There are additional advantages resulting specifically from these forming techniques which should be noted.



Bell housing *was drawn in 0.032-in. thick copper in one Hydroform operation compared to 3 operations with conventional draw dies. Punch, at left, is 1020 steel.*

(Cincinnati Milling Machine Co.)

Reduction in number of drawing steps—Maximum percentage of reduction practical with matched draw dies is around 45 to 50%, under optimum conditions of tooling and metal. Percentage reduction is calculated by the following equation:

$$\% \text{ Red} = 100 - \frac{\text{cup dia}}{\text{blank dia}}$$

The reductions possible in successive drawing steps are scaled down progressively. A typical reduction progression might be 30, 25, 22, and 15%. In drawing a shape with flexible female dies, reductions of up to 80% have been accomplished in one operation, though it is not common. Commonly encountered reduction figures for one-step flexible die drawings range around 60 to 65%. By eliminating draw steps, obvious advantages result from reduction in number of tools, annealing and cleaning steps and time. The subject will be discussed more fully in the section on design considerations.

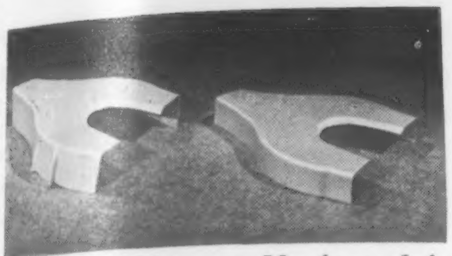
Consistent quality throughout each part—There is a reduction in spot stresses, thin-out and springback due to the continuous wrap-around action and equalized, controlled forming pressure distributed over the entire blank during forming.

Limitations

Pressures—At present, maximum forming pressures are limited to 15,000 psi for Hydroform and 12,000 psi for Marform.

Shapes—The methods are usually not too feasible for forming parts with secondary recesses of such a depth that forming involves a large degree of shrinkage. Parts requiring only simple or curved flanges, are generally more economical to form on a rubber pad press.

Cost of press—The cost of a Hydroform or a Marform press represents a substantial capital investment. The quantity and type of production should be



Part at right *was Marformed in a single operation in 17 sec with no subsequent hand-work. Wrinkled part at left was formed on rubber pad press and required 5 to 7 min to hand-finish. Material is 0.032-in. 2024 aluminum with a flange depth of 7/8 in.* *(Glenn L. Martin Co.)*

carefully evaluated in light of the press cost.

Sheet materials

In general, any sheet metal that can be drawn can be drawn by these methods. There are certain limitations as to gage, imposed by the maximum pressures of the press. These will be discussed in the subsequent section. The majority of parts produced by flexible die forming today are probably in the heat-treatable aluminum alloys such as 2014, 2024, 6151, and 7075. One manufacturer uses alclad aluminum sheet which reduces orange peel effects on the finished part, providing a 40% saving in buffing and finishing costs. Other sheet materials used include stainless steels, AISI 1010 deep drawing carbon steel, stainless-clad copper, Inconel, L-605, brass, aluminized steel and magnesium.

Design considerations

At the present state of knowledge concerning these relatively new drawing methods, it would be impractical to draw definitive lines as to gage of material, condition and percentage reduction possible in one drawing operation. A rough approximation might be that sheet material thicknesses are currently limited to about 3/8 in. Each case will be different, however, and trial and error is the most effective way of judging accurately what the methods will do. By pointing out some results of work done to date and the forming principles involved a general idea of the types of parts can be obtained.

EFFECT OF BLANK THICKNESS ON MAXIMUM CUP HEIGHT WITH SAME REDUCTION HYDROFORM PROCESS
(15,000 psi Forming Pressure)

Blank Dia, in.	Cup Dia, in.	Cup Ht, in.	Thickness, in.
12	4¼	5⅛	0.064
12	4¼	4⅞	0.050
12	4¼	4¾	0.037
12	4¼	4½	0.032

Cincinnati Milling Machine Co.

Of course, the processes do not change the inherent characteristics and properties of the sheet materials formed. The maximum forming limits of a particular metal are not changed. However, the peculiar characteristics of flexible die drawing do increase the formability of the material thus allowing more severe deformation in one drawing step and reducing the number of operations required to reach the deformation limits of the material. In one case, for example, switching from matched dies to flexible female dies eliminated eight operations in the production of a part. The eight operations consisted of subsequent draws, annealing and pickling operations.

The increased percentage of reduction possible in one draw is due to several factors inherent in the forming technique. The forming forces exerted by matched metal draw dies are perpendicular to the blank. As the punch moves into the die, high localized strains develop in the areas in contact with the punch radius if the top of the punch is flat. Or in the case of domed shapes or irregular shaped parts, localized strains occur in those areas being

These parts *were Marformed in one operation with the exception of "H" which required a restrike:*

A—Material: 0.040 in. thick, 2024-O aluminum.
Dimensions: 4⅝ in. dia, 1 3/16 in. deep.
B—Material: 0.030 in. thick, 1010 steel.
Dimensions: Overall, 3⅛ x 4½ in., 1¾ in. deep.
C—Material: 0.072 in. thick, 7075-O aluminum.
Dimensions: Overall, 8¾ x 10½ in., 2-in. flange depth.
D—Material: 0.375 in. thick, 6061-O aluminum.
Dimensions: 7 in. dia, 3⅞ in. deep.
E—Material: 0.010 in. thick, 1100-O aluminum.
Dimensions: Overall, 3 x 5 in.
F—Material: 0.078 in. thick, type 347 stainless steel.
Dimensions: Main section, 17 in., with 2½-in. radius.
Port length, 9 in., with 1½-in. radius.
G—Material: 0.064 in. thick, 6061-O aluminum, pre-coated with navy blue paint.
H—Material: 0.040 in. thick, 1100-O aluminum reflector sheet stock.
Dimensions: 4 in. deep, 8-in. opening dia, 4⅝-in. bottom dia.
(Hydropress, Inc.)

formed by the prominent areas of the punch. The rubber forming medium, on the other hand, exerts a lateral as well as vertical pressure during forming which, in effect, locks the metal already formed to the male punch, preventing the accumulation of strains at the punch radius. The flexible die member thus provides consistent forming pressures and distributes the strains evenly over the sheet's entire area. Prevention of strain concentration at the punch radius allows deeper drawn parts as well as parts with uniform thickness throughout.

Another factor which increases deformation possible in one draw is the variable die radius provided by the rubber. Die radii on matched metal dies are incorporated in the draw ring and are unchangeable. The die radius provided by the flexible female die member is formed by the rubber diaphragm or pad. The initial die radius when the press is closed is 180 deg. As the punch moves up into the rubber pad or hydraulic cavity and draws the blank, the radius decreases gradually as pressure increases until maximum depth of draw is reached; the radius has then reached the minimum.

One advantage Hydroforming holds over Marforming is in sharpening or "edging" external radii. Should the required radius be smaller than that which can be formed during the drawing operation, the punch can be backed slightly while maintaining full pressure in the hydraulic cavity. The backing of the punch will sharpen up most external radii including the die radius. Should a sharper radius be required on a Marformed part a restrike is generally necessary on another press. The same tooling may be used with addition of a radius plate and mounting spacers.

Minimum allowable radii on parts to be formed with flexible female dies will vary directly in proportion to metal thickness. Generally internal radii should be kept to at least 3/32 in., while external radii should not be less than 1/8 in.

Drawing sheet metal with matched metal dies generally involves large unsupported areas since support of the blank is only maintained at prominent areas of the punch and at the draw ring. Large unsupported areas produce varying degrees of thin-out as well as the localized strains discussed previously. In conventional die drawing, unsupported areas are reduced by increasing the number of drawing steps. When drawing with flexible dies, unsupported areas must be kept to a minimum also, though their importance is reduced since the rubber is exerting pressure on the entire blank during all stages of the draw. As a rule, size of unsupported areas should not exceed twice that of the supported areas. Pre-forming the blank can help to reduce the unsupported area. For example, drawing such shapes as cones or step-cones usually involves relatively large unsupported areas between the punch point or dome and blank holder. By pre-forming, the punch can be raised into the preformed area, reducing area between punch and blank holder.

Blanks can be pre-formed in a variety of ways. Drop hammers are often used, or rubber pad presses, depending on the configuration. A conventional draw press may also be used. Since deformation during pre-forming is usually not great, several blanks may be pre-formed in one operation with matched dies thus reducing the tooling cost per part. Another method is use of a blow-down die. Blowdown dies contain a cavity the size of the desired pre-form. The pressure of the flexible die medium forces the sheet metal down into the cavity and generally will provide a satisfactory shape for a pre-formed part.

Flexible female die drawing methods can also be used to blank or pierce holes in the bottom of cups. A recess is formed in the punch top which leaves that segment of the blank unsupported and the pressure blanks out that

RECOMMENDED SINGLE DRAW LIMITATIONS FOR MARFORM PROCESS

Cup Dia, in.	Safe Max Depth of Draw, in. Forming Pressure		Min Thickness, in.
	6000 psi	12,000 psi	
1	1/3	3/4	0.008
2	2/3	1 1/2	0.010
3	1	2 1/4	0.015
4	1 1/3	3	0.020
5	1 2/3	3 3/4	0.025
6	2	4 1/2	0.030
7	2 1/3	5 1/4	0.035
8	2 2/3	6	0.040

Glenn L. Martin Co.

SAFE MINIMUM PUNCH RADIUS RELATIVE TO MATERIAL THICKNESS (T) FOR DRAWING CUPS

Ratio of Draw Depth to Draw Diameter	Steel		Aluminum	
	SAE 1010	Stainless Types 302, 304	1100-0, 3003-0, 5052-0 and 6061-0	2024-0, 2014-0 and 7075-0
1/4	1/2T	2T	1T	2T
1/2	1T	—	2T	3T
3/4	2T	—	3T	4T
1	—	—	4T	—

area. A cup can be trimmed by forming a sharp step-back into the punch body. Care should be taken, however, that the rubber is not gouged or cut excessively during the trimming or blanking.

Both the Hydroform and the Marform press can also be used as high pressure rubber pad presses. A flat platen may be substituted for the punch, and form blocks mounted on it. The pressures can be regulated to any point up to the maximum capacity of the unit.

Drawing and Embossing With Flexible Punches

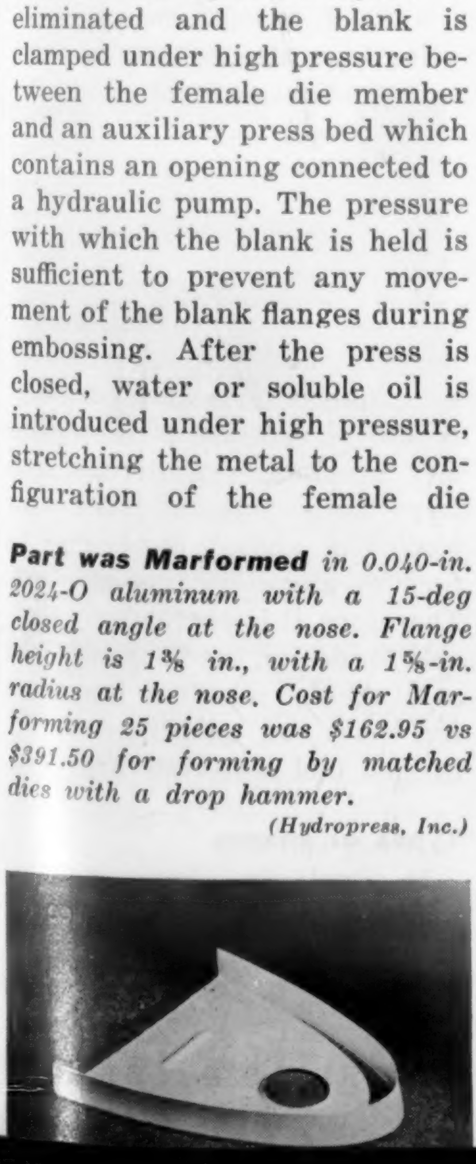
Drawing with a flexible punch is exemplified by the so-called Hydrodynamic Process of S. B. Whistler & Sons, Inc. It involves a solid die for the female member and water or soluble oil under high pressure for the male punch. The blank is clamped between the upper female die and a spring-loaded pressure plate which prevents wrinkling of the sheet during forming. High pressure water or soluble oil is then injected through an orifice in the pressure plate and acts as the die punch in exerting uniform drawing pressure against the entire blank until it conforms to the shape of the solid female member.

For embossing parts, where only stretching is involved, the spring-loaded pressure plate is eliminated and the blank is clamped under high pressure between the female die member and an auxiliary press bed which contains an opening connected to a hydraulic pump. The pressure with which the blank is held is sufficient to prevent any movement of the blank flanges during embossing. After the press is closed, water or soluble oil is introduced under high pressure, stretching the metal to the configuration of the female die member.

The only tooling required is a female die member equipped with vents for release of air during forming.

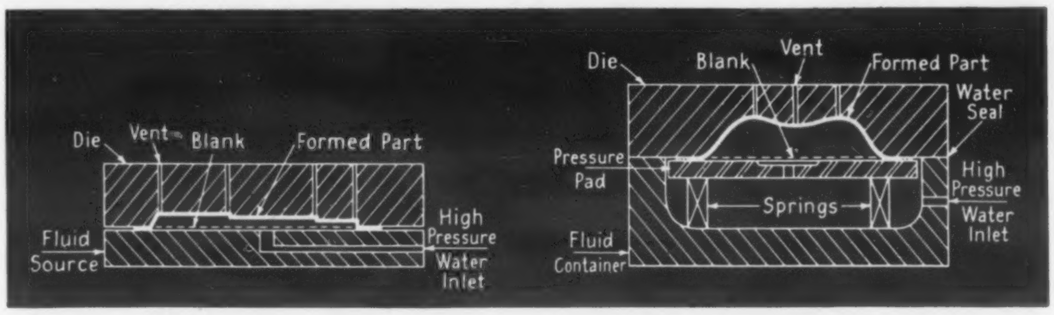
Part was Marformed *in 0.040-in. 2024-O aluminum with a 15-deg closed angle at the nose. Flange height is 1⅜ in., with a 1⅝-in. radius at the nose. Cost for Marforming 25 pieces was $162.95 vs $391.50 for forming by matched dies with a drop hammer.*

(Hydropress, Inc.)

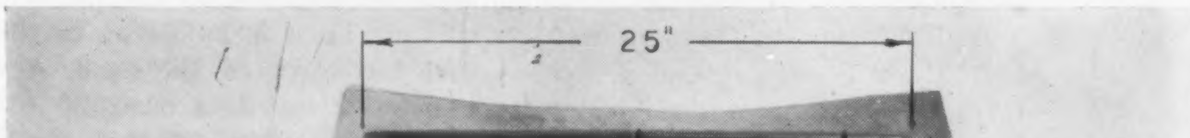


Capabilities and limitations

The process is particularly well suited to forming shallow sweeps, drawing cone and tapered shapes and embossing



Embossing *Drawing*
Hydrodynamic Operation *(International Nickel Co.)*



Typical parts *formed in a variety of materials by the Hydrodynamic process which uses a flexible male punch.* *(S. B. Whistler & Sons, Inc.)*

multi-cavity and unsymmetrical shapes.

The advantages common to all flexible die forming methods apply to the Hydrodynamic process. There are some additional advantages specifically inherent in the process which should be pointed out.

Reduction in draw steps—Many tapered and cone shaped parts which would require several draw steps and intermediate anneals with conventional press-forming can be drawn in one step.

Consistent quality throughout each part—There is a reduction in thin-out and spot stresses since drawing pressure is exerted in every direction simultaneously. There is no sharp-nosed punch to accumulate strains in the metal. The initial punch diameter is, in effect, the same diameter as the exposed section of the blank. As the part is formed, effective punch diameter decreases to the diameter of the deepest section of the female die.

A limitation of the process is that it is not intended for forming straight walled drawings since they can generally be made more economically on mechanical presses.

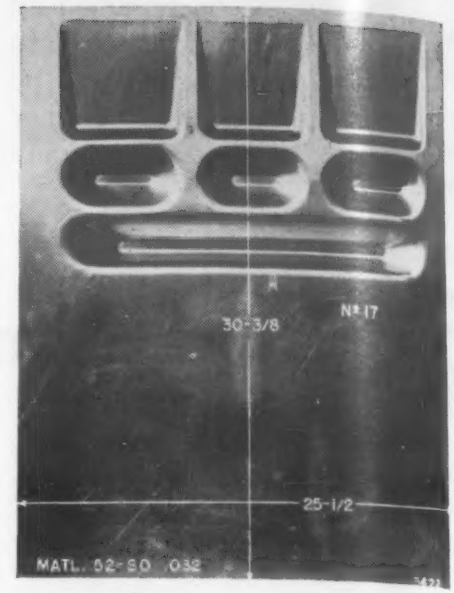
Besides the conventional sheet metals, the process is said to be especially suited to drawing enameled or precoated sheet materials. Some shapes can be drawn or embossed in fully tempered and hardened aluminum alloys, eliminating subsequent heat treatment and resulting distortion.

Design considerations

As an industrial metal-forming technique, flexible punch drawing and embossing is relatively new and its limitations have not been fully determined. To date, sheet materials up to around 3/16 in. have been formed successfully.

The bottom radii of the cup (conventionally the punch radii) formed with the fluid punch must be larger than conventional die forming, since the forming force is proportional to the hydraulic pressure and the unsupported metal area. Thus, as the metal is shaped against the die walls and the radii become smaller, there is less unsupported metal against which the fluid pressure may work. The area decreases until the material's strength is sufficient to resist the force of the fluid. According to test data, on 0.020 in.-thick type 310 stainless steel, annealed, the minimum radii with 5500-psi water pressure is 0.406 in.

Though it is impossible as yet to set down definitive limitations on designing for flexible punch forming, a description of a few parts which have been successfully formed in one operation should indicate some of the common applications.



***Aircraft part** formed in 0.032-in. 5052-O aluminum by the Hydrodynamic process.*
(S. B. Whistler & Sons, Inc.)

Cone: drawn in 18:8 stainless steel. Diameter is 21 in., depth of draw, 6 in.

Tapered dish: drawn in 0.062-in. thick 1020 steel. Diameter of face of dish is 18 in., diameter at bottom of 4½ in. deep draw is 13½ in.

Embossed shape of wing: in 0.050-in. thick Armco Enameling Iron, also in 0.031-in. thick 18:8 stainless steel. Same die was used.

Drop Hammer

Basically, the drop hammer is a large, mechanically operated hand hammer. It accomplishes the same general type of forming as the hand operation. Of course, it provides much higher impact to the forming blows, but with the drop hammers most widely used in industry today the force of the blows can be regulated from a feather-like touch to a blow whose force is much greater than that provided by the free-fall weight of the ram itself. Since the forming is carried out by numerous blows of varying magnitude, drop hammers are particularly well suited to forming intricate and large parts. Though essentially a single-action press, there are many auxiliary devices which can provide double-action forming characteristics.

Since the forming pressure can be regulated and various devices used to alter the forming technique, the shapes and accuracy of shapes is to a large extent dependent on the skill of the operator. He must be able to visualize the flow of the metal during forming and to regulate his technique as forming progresses. A skillful, experienced drop hammer operator can develop and form many types of parts that would be almost impossible to form on any other type of press. Therefore, it is particularly suitable for design development. Tool costs are also relatively low, since for short run quantities, easily formed tool materials are used.

Types of shapes

In simple drop hammer work, there is no hold down force on

the blank; therefore, commonly encountered shapes have flanges and shallow depressions rather than drawn recesses. Parts are formed rather than drawn. Relatively deep draws can occasionally be accomplished with auxiliary devices and fixtures. Reverse contours and saddleback shapes are particularly difficult to form with a drop hammer.

Equipment

There are two basic types of drop hammers. With the rope hammer, a rope or cable is used to raise ram and male punch to the height of release. The ram is dropped and the weight of the ram and punch free-falling on the blank and female die member form the part. The double-acting hammer, more commonly used today, is operated by pneumatic, hydraulic or steam pressure. The pressure both raises and lowers the ram and punch, adding to the forming impact of the punch and providing close control over the force of impact.

Matched dies for short run operations are generally cast in Kirksite. For extremely short runs a lead punch is often used, though its softness greatly restricts the number of accurate parts that can be made. The low pouring temperatures permissible with Kirksite and lead permit economic and accurate forming of the two die members. Kirksite may be formed directly against a plaster mold and the lead punch may be poured directly against the completed Kirksite female. Cast iron may be used for dies for longer runs. Recently, nodular or ductile iron has also been successful.

Support flange *is formed in 0.051-in. thick annealed aluminum sheet on a drop hammer with a rubber pad replacing the conventional female die. Only a Kirksite form block is required. Forming pressure is 8750 psi. Cost reduction through use of the trapped rubber head is about 25%.* *(Boeing Airplane Co.)*

There has been quite a bit of interest, particularly in the aircraft industry, in the use of trapped rubber heads in conjunction with Kirksite punches for drop hammer work. The Kirksite punch is installed on the bed of the hammer. The rubber ram face is similar to that used for rubber pad hydraulic press forming. As yet not a great deal of reliable data has been gathered to indicate the limitations on the types of parts that can be formed.

Another recent tooling material presently undergoing evaluation is plastics. Successful use of plastics for drop hammer dies has been somewhat limited due to the high impact of the forming blows; however, cast ethyl cellulose and a cast resilient epoxy face over a Kirksite core are two applications which seem to have provided the best results to date.

Various auxiliary devices and techniques are used to aid in forming difficult parts and to permit effective forming of parts which could not be formed without them. Raw rubber or rubber throw pads are used to provide additional pressure in localized areas of the blank. They are also used to iron out buckles and wrinkles in recessed areas, or to provide a hold-down force for a drawn shape. Rigid draw rings made of boiler steel plate or plywood, 1/4 to 1 in. thick, may be used to prevent wrinkling around the periphery of a drawn area. Another method of simulating the hold-down action of double-action press dies is incorporation of beads or traps in the drop hammer dies' surfaces, or flanging the edges of the blank over the die's outside corner.

Although the majority of drop hammer formed parts can be formed with one set of dies, where several forming stages are necessary, stage dies may be used. The most efficient type of stage die is a block die containing impressions shaped so as to form each successive stage of the forming operation. The same effect can sometimes be gained by placing lead blanks in the bottom of a die recess and removing them after the first forming operation. In effect, the lead blanks decrease the cavity depth for the primary forming step.

Advantages and limitations

The advantages of drop hammer forming are as follows:

Low tool cost—The cost of tool fabrication is relatively low since the die set can be cast directly against the plaster mold when using Kirksite (melting point 720 F). If a lead punch can be used, the lead (melting point around 600 F) can be cast directly against the Kirksite female. Precautions of course, should be taken to compensate for shrinkage during solidification of the

Formed on drop hammer *with a trapped rubber head, this stiffener for a spoiler skin is made of 0.040-in. thick, 7075-T6 alclad aluminum. Cost reduction over old method of forming with a rubber pad press and finish-forming by hand is about 35%.* *(Boeing Airplane Co.)*

molten metal.

Short lead time—Due to the rapidity of die fabrication, elapsed time between design and production is generally minimized.

Flexibility—A wide variety of shapes can be formed since the forms possible are dependent on the operator's skill. Additional flexibility is available through use of auxiliary forming devices. Parts difficult to form on conventional presses often can be formed with a drop hammer.

The method's limitations are as follows:

Small production volume—Variations in locating and controlling the flow of the blank usually make the use of rough blanks mandatory. Since trimming a formed shape is more costly than trimming a blank, the use of rough blanks limits the quantity of parts which can be economically formed. In cases where several blows are required to form a part, drop hammer work may be a relatively slow process. However, this may not be considered a disadvantage in cases where the only alternative is hand-forming.

COMPARATIVE FORMABILITY RATINGS OF VARIOUS METALS[a]

Metal	Alloy	Rating
Aluminum	1100-0	100
	3003-0	95
Magnesium (Hot Formed)	—	95[b]
Aluminum	6061-0	92
	5052-0	80
	7075-0	75
	2024-0	75
	2014-0	75
Deep Drawing Steel	1010	75
Soft Copper	—	75[b]
Commercial Steel	1010	70
Soft Brass	—	70
Aluminum (As Quenched)	7075-W	60
	2024-W	60
	2014-W	60
Aluminum	1100-¼H	50
Stainless Steel	Type 302	49
	Type 304	46
Aluminum	3003-¼H	45
Stainless Steel	Type 321	43
Aluminum	5052-¼H	40[b]
	1100-½H	40[b]
Stainless Steel	Type 347	40
Aluminum	3003-½H	35[b]
	5052-½H	30[b]

[a] *Based on rating of 100 for 1100-0 aluminum.*
[b] *Tentative.*

Materials

Drop hammers are most commonly used to form heat treatable aluminum alloys such as 2014, 2024 and 7075. As a rule, parts should be formed in the annealed condition, to nearly the final shape, with intermediate anneals as necessary. After final heat treatment finish-forming with the drop hammer will eliminate distortion or wrinkling caused by the heat treatment. For more complex shapes with deeper recesses, materials with higher stretch limits, such as 5052-O are used. Relatively complex shapes can be formed in 2024-O in thicknesses up to 0.125 in., while simpler shapes can be formed up to around 0.250 in. In the as-quenched condition, thicknesses over 0.051 in. are rarely formed on drop hammers.

Other materials which can be formed include the austenitic stainless steels and some super alloys in their softest condition. Shapes in such materials are limited to rather shallow and simple forms. Stainless steels should generally be formed with one blow, though alloys in the ¼-hard condition may require up to 3 or 4 strikes, usually with intermediate anneals. Pickling is not necessary normally until after the final anneal prior to finish forming. Stainless steel parts intended for high temperature use, after being formed with zinc alloy dies should be carefully pickled since there is usually a good deal of zinc pick-up which must be removed to prevent subsequent cracking at service temperatures. Sheet metal thinner than 0.018 in. should not be drop hammer formed as it will form wrinkles difficult to remove. Sheets of annealed stainless steels usually do not exceed 0.078 in. for drop hammer forming. The usual range of thicknesses is 0.024 to 0.063 in. The sheet materials should be supplied with a smooth, cold-rolled finish to minimize die wear.

Design considerations

There are relatively few restrictions on the type of shape which can be formed since a skilled operator can usually develop a forming method for most any part. Though most parts can be formed with one die, in certain instances a second die may be useful for setting general contour and particularly for setting sharp radii. Though parts with shallow recesses are well suited to drop hammer forming, they require special attention due to the spring-back of the strain-hardened sheet. Trial and error is generally the only compensating method.

Recesses in parts shaped by drop hammers are limited both in depth and contour. With a single die, using an auxiliary draw ring, cup- or dome-shaped, parts can be formed to a depth of about 60 to 70% of that obtainable with double action dies. Square and rectangular boxes require a minimum corner radius of ¼ in. or 5 times the metal thickness, whichever is larger. Deeper boxes, regardless of their width, require larger corner radii, although minimum allowable corner radius or maximum box depth also depend on the width of the box. Therefore, maximum depth may be limited to a smaller value than that governed by the corner radius.

Acknowledgment

In preparing this manual a great deal of the information on sheet metal forming was gathered from "Principles and Methods of Sheet Metal Fabricating," by G. Sachs, Reinhold Publishing Corp., 1951, and "Forming of Austenitic Chromium-Nickel Stainless Steels," The International Nickel Co., Inc., 1954.

The assistance of the following companies is also acknowledged:

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MATERIALS ENGINEERING FILE FACTS

MATERIALS & METHODS · MARCH 1955 · NUMBER 296

MATERIALS DATA SHEET

Cast Stainless Steels

ACI TYPE	CA-15	CA-40	CB-30	CC-50
COMPOSITION—%	Cr 11.5–14.0 Ni 1.0 max C 0.15 max Mn 1.0 max Si 1.5 max	Cr 11.5–14.0 Ni 1.0 max C 0.20–0.40 Mn 1.00 max Si 1.50 max	Cr 18–22 Ni 2.0 max C 0.30 max Mn 1.00 max Si 1.00 max	Cr 26–30 Ni 4.0 max C 0.50 max Mn 1.0 max Si 1.0 max
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.275	0.275	0.272	0.272
Melting point F	2750	2725	2725	2725
Therm Cond, Btu/hr/sq ft/ft/°F, at 212 F	14.5	14.5	12.8	12.6
Coef of Exp per °F: 70–1000 F	6.4×10^{-6}	6.4×10^{-6}	6.5×10^{-6}	6.4×10^{-6}
Spec Ht, Btu/lb/°F at 70 F	0.11	0.11	0.11	0.12
Elect Res, microhm-cm at 70 F	78	76	76	77
Magnetic Properties	Ferromagnetic	Ferromagnetic	Ferromagnetic	Ferromagnetic
MECHANICAL PROPERTIES AT ROOM TEMP				
Mod of Elast in Tension, psi	29×10^6	29×10^6	29×10^6	29×10^6
Ten Str, 1000 psi:				
Annealed	—	—	95[d]	97[e]
As cast	—	—	—	70-95
Hard and Temp	200[a]	220[a]	—	—
Hard and Temp	100[b]	110[c]	—	—
Yld Str, (0.2% offset) 1000 psi:				
Annealed	—	—	60[d]	65[e]
As cast	—	—	—	60-65
Hard and Temp	150[a]	165[a]	—	—
Hard and Temp	75[b]	67[c]	—	—
Elong in 2 in., %				
Annealed	—	—	15[d]	18[e]
As cast	—	—	—	2-15
Hard and Temp	7[a]	1[a]	—	—
Hard and Temp	30[b]	18[c]	—	—
Hardness, Bhn:				
Annealed	—	—	195[d]	210[e]
As cast	—	—	—	193-212
Hard and Temp	390[a]	470[a]	—	—
Hard and Temp	185[b]	212[c]	—	—
Impact Str, Charpy (keyhole notch) ft-lb:				
Annealed	—	—	2[d]	—
As cast	—	—	—	2-45 (Izod V Notch)
Hard and Temp	15[a]	1[a]	—	—
Hard and Temp	35[b]	3[c]	—	—
THERMAL TREATMENT				
Annealing Temp, F	1450–1650 f.c.	1450–1650 f.c.	1450, f.c.—1000, a.c.	1450, f.c. or a.c.
Hardening Temp, F	1800–1850 a.c. or o.q.	1800–1850 a.c. or o.q.	Practically nonhardenable by heat treatment	Nonhardenable by heat treatment
Tempering Temp, F	<600 or 1100–1500 High-est strength by tempering below 600	<600 or 1100–1500 High-est strength by tempering below 600	—	—
FABRICATING PROPERTIES				
Casting	Section thicknesses from 3/16 in. up can be cast satisfactorily. Somewhat lighter sections can be cast in some parts. Difficult-to-run thin sections and designs involving appreciable changes in section should be avoided. Normal pattern-makers shrinkage for these alloys is 1/4 in. per foot with the exception of CC-50, where it is 7/32 in. per foot			
Weldability	Can be welded by metal arc, inert gas arc and oxyacetylene gas methods. Metal arc most frequently used. Oxyacetylene welding not advisable because of possible reduction in corrosion resistance resulting from carbon pick-up. Castings should be preheated before welding and receive a post weld heat treatment			
CORROSION RESISTANCE	Good atmospheric corrosion resistance. Excellent resistance to many organic media in relatively mild service	Similar to CA-15	Resistant to nitric acid, alkaline solutions, many organic chemicals, oxidizing atmospheres up to 1400 F	Excellent resistance to dil sulfuric acid in mine waters, mixed nitric and sulfuric acids and oxidizing acids of all types
USES	Pump casings, bushings, and liners, impellers, shafts, turbine blades, stuffing boxes, valve bodies and trim, fittings, furnace burner tips and pilot cones	Choppers, cutting blades, cylinder liners, pump parts, steam turbine parts, molds, dies	Furnace brackets and hangers, pump parts, rabble arms, tube supports, valve bodies and parts	Bushings, cylinder liners, pump casings and impellers, valve bodies and seats

(*Table continued on next page*)

NOTES:
- [a] *Air cooled from 1800 F, tempered at 600 F.*
- [b] *Air cooled from 1800 F, tempered at 1450 F.*
- [c] *Air cooled from 1800 F, tempered at 1400 F.*
- [d] *Annealed at 1450 F, furnace cooled to 1000 F, air cooled.*
- [e] *Air cooled from 1900 F.*

◀ For more Information, Circle No. 521

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Cast Stainless Steels — continued

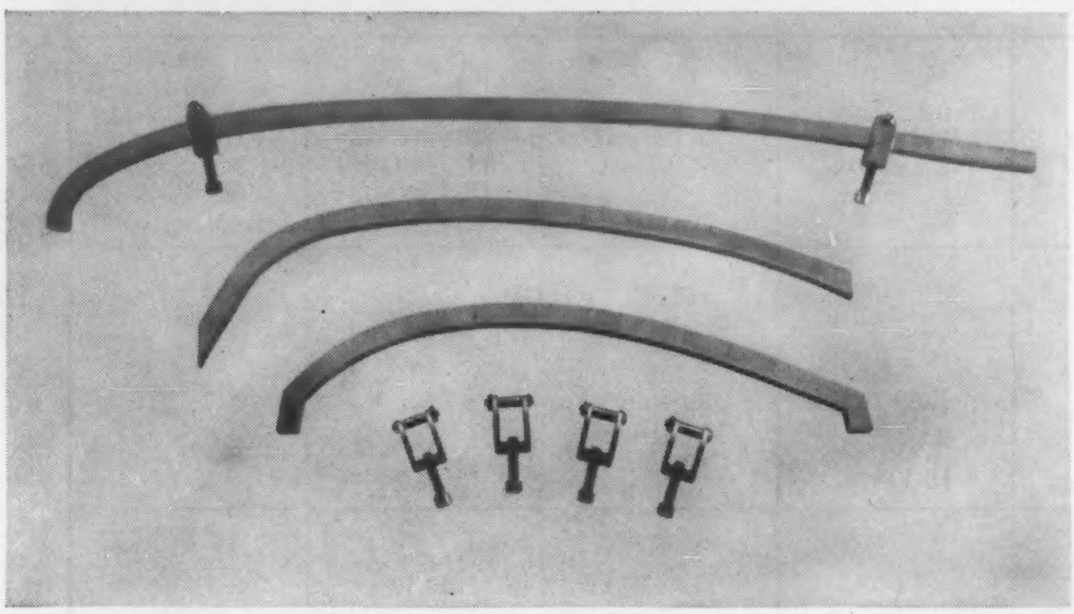
ACI TYPE	CE-30	CF-8	CF-20	CF-8M CF-12M	CF-8C
COMPOSITION—%	Cr 26–30 Ni 8–11 C 0.30 max Mn 1.50 max Si 2.00 max — —	Cr 18–21 Ni 8–11 C 0.08 max Mn 1.50 max Si 2.00 max — —	Cr 18–21 Ni 8–11 C 0.20 max Mn 1.50 max Si 2.00 max — —	Cr 18–21 Ni 9–12 Mo 2.0–3.0 C 0.08 (CF-8M) 0.12 (CF-12M) Mn 1.50 max Si 2.00 max	Cr 18–21 Ni 9–12 Cb 8 x C min <1.0 C 0.08 max Mn 1.50 max Si 2.00 max —
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.277	0.280	0.280	0.280	0.280
Melting Point F	2650	2600	2575	2550	2600
Therm Cond, Btu/hr/sq ft/ft/°F, at 212 F	—	9.2	9.2	9.4	9.3
Coef of Exp per °F: 70–1000 F	9.6×10^{-6}	10.0×10^{-6}	10.4×10^{-6}	9.7×10^{-6}	10.3×10^{-6}
Spec Ht, Btu/lb/°F at 70 F	0.14	0.12	0.12	0.12	0.12
Elect Res. microhm-cm at 70 F	85	76	78	82	71
Magnetic Permeability	>1.5	1.0–1.3[a]	1.01	1.50–2.50	1.20–1.80
MECHANICAL PROPERTIES AT ROOM TEMP					
Mod of Elast in Tension, psi	25×10^6	28×10^6	28×10^6	28×10^6	28×10^6
Ten Str. 1000 psi:					
As Cast	95	—	—	—	—
Water quenched from 2000 F	97	77	77	80	77
Yld Str, (0.2% offset) 1000 psi:					
As cast	60	—	—	—	—
Water quenched from 2000 F	63	37	36	42	38
Elong in 2 in., %:					
As cast	15	—	—	—	—
Water quenched from 2000 F	18	55	50	50	39
Hardness, Bhn:					
As cast	170	—	—	—	—
Water quenched from 2000 F	170	140	163	156–170	149
Impact Str, Charpy (keyhole notch) ft-lb:					
Water quenched from 2000 F	—	74	60	70	30
THERMAL TREATMENT					
Quenching Temp, F	1950–2050 water, oil or air quenched	1950–2050 water, oil or air quenched	2000–2100 water, oil or air quenched	1950–2100 water, oil or air quenched	1950–2050 water, oil or air quenched
FABRICATING PROPERTIES					
Casting	Section thicknesses from 3/16 in. up can be cast satisfactorily. Somewhat lighter sections are also possible in some parts. Good castability of these alloys permits designs involving intricate shapes but drastic changes in section should be avoided and uniform thickness should be maintained as far as possible				
Weldability	Can be welded by metal arc, inert gas arc, and oxyacetylene gas methods. Metal arc most frequently used. oxyacetylene welding not advisable because of possible reduction in corrosion resistance caused by carbon pick-up. Preheating is not necessary but castings should be quenched from the range 1950 to 2100 F to restore maximum corrosion resistance. This heat treatment is not always necessary, however, with CE-30 and CF-8C alloys				
CORROSION RESISTANCE	Particularly resistant to sulfurous acid; mixtures of dil. sulfuric and sulfurous, sulfuric and nitric; sulfites	Resistant to strongly oxidizing media such as boiling nitric acid, sulfuric acids, and sulfates, organic acids	Similar to CF-8 but used under less drastic conditions	Resistant to reducing media; more resistant to pitting corrosion than CF-8 in contact with chloride; not as resistant to boiling nitric acid as CF-8	Similar to CF-8
USES	Process industry equipment such as digester fittings, fractionating towers, piping, pump bodies and casings. valve bodies and parts	Autoclaves. blast-furnaces, bushings, filter press plates, hardware, headers and heating coils, pump parts, spray nozzles, valve parts	Cylinder liners, pumps, return bends, rolls, circuit breaker parts, valve parts	Agitators, evaporator parts, jet engine components, spray nozzles, high pressure steam valves	Aircraft shroud assemblies. autoclaves chemical tubing, fittings, jet engine parts, marine fittings

NOTES:
[a] *After heat treatment.*

(Table continued on next page)

Plastiatrics

DOW'S CLINICAL APPROACH TO HEALTHY PLASTICS APPLICATION



Bending Test Forms and Clamps.

NEW TECHNIQUE OF STRESS MEASUREMENT DEVELOPED FROM STUDY OF POLYSTYRENE BEHAVIOR

In Plastiatrics, as in medicine, sound diagnosis is essential to correct treatment and the cure of problems. That's why The Dow Technical Service laboratories have developed a simplified test procedure for the study of the *crazing* of molded polystyrene . . . a condition which may result from misunderstanding or improper application of a molded plastic part. Of significance to engineers and plastics molders, the new data on polystyrene's "critical elongation" is of fundamental importance in product design and in predicting field service life.

What is Crazing?

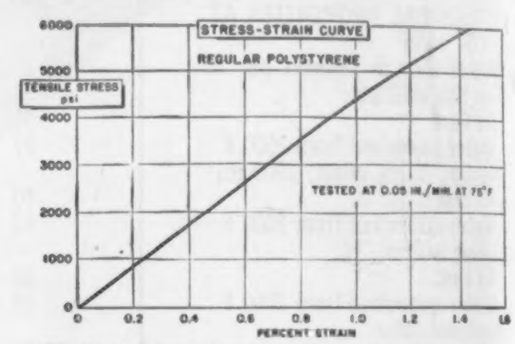
Crazing is the development of fine cracks on or under the surface of molded plastics. Whether or not it progresses to serious proportions is dependent on several variables of exposure and applied stress over a period of time. "Solvent crazing" may be derived from the chemical action of a wide variety of reagents. "Stress crazing" may result from mechanical loading, shock, thermal conditions, or from the molding operations.

Simple Test Developed

To maintain standard conditions while handling of immersing specimens in a variety of reagents, a simple, portable bending form was developed. It's designed to provide a constantly changing radius of curvature and corresponding stress as well as strain in the test specimen. Percent elongations can be calculated accurately and varied over a wide range while cold flow is virtually eliminated regardless of the length of time needed for the test. By close visual examination of the stressed specimen in bright light, it is possible to observe the minute cracks and ascertain the magnitude of the crazing in relation to the amount of stress. Excellent correlations of results have been established with critical elongation values taken from conventional testing equipment, as well as with field tests of molded products. Effects of time, temperature reagents, and exposure can be studied in detail.

Practical Uses for Engineering

From the data, the design engineer can more definitely predict stress behavior of molded polystyrene parts. For example, studies on the effects of various milk products on tumblers indicate varying degrees of useful life. Lactic acid is found to have less affect on weakening polystyrene than butterfat has. Test results established critical stress for skim milk at 750 p.s.i. as against 450 p.s.i. for cream. When the tumbler is subject to very hot water in the presence of cream (butterfat), critical stress is further depressed (to about 200 p.s.i.) leaving little room for internal molding stresses or mechanical leading stresses resulting from stocking, rough handling or dropping. Thus, it becomes possible to predict the margin of residual stress which will result in satisfactory tumblers . . . or to forecast potential crazing difficulties.



Typical Stress-Strain curve of polystyrene.

Free Bulletin Offered

A considerable amount of data on this test method has been compiled and published in a bulletin entitled "The Crazing of Polystyrene." A copy will be sent free upon request. Write to Plastics Sales Department PL454X, THE DOW CHEMICAL COMPANY, Midland, Michigan.

DOW POLYSTYRENE FORMULATIONS:

- Styron® 666. . . Dow general-purpose polystyrene.
- Styron 688 . . . for controlled flow and controlled pressure distribution in the mold cavity.
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MATERIALS ENGINEERING
FILE FACTS
MATERIALS & METHODS · MARCH 1955 · NUMBER 296

Cast Stainless Steels — continued

ACI TYPE	CF-16F	CH-20	CK-20	CN-7M
COMPOSITION—%	Cr 18–21 Ni 9–12 C 0.16 max Mo 1.50 max Se 0.20–0.35 Mn 1.50 max Si 2.00 max	Cr 22–26 Ni 12–15 C 0.20 max Mn 1.50 max Si 2.00 max — —	Cr 23–27 Ni 19–22 C 0.20 max Mn 1.50 max Si 2.00 max — —	Cr 19–22 Ni 27.5–30.5 Mo 1.75–2.50 Cu 3.00 min C 0.07 max Mn 1.50 max Si 1.50 max
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.280	0.279	0.280	0.289
Melting Point, F	2550	2600	2600	2650
Therm Cond, Btu/hr/sq ft/ft/°F, at 212 F	9.4	8.2	8.2	12.1
Coef of Exp per °F: 70–1000 F	9.9×10^{-6}	9.6×10^{-6}	9.2×10^{-6}	9.7×10^{-6}
Spec Ht, Btu/lb/°F at 70 F	0.12	0.12	0.12	0.11
Elect Res, microhm-cm at 70 F	72	84	90	90
Magnetic Permeability	1.0–2.0	1.71[a]	1.02	1.01–1.10
MECHANICAL PROPERTIES AT ROOM TEMP				
Mod of Elast in Tension, psi	28×10^6	28×10^6	29×10^6	24×10^6
Ten Str, 1000 psi: Water quenched from 2000 F	77	88	76	69
Yld Str, (0.2% offset) 1000 psi: Water quenched from 2000 F	40	50	38	31.5
Elong in 2 in., %: Water quenched from 2000 F	52	38	37	48
Hardness, Bhn.: Water quenched from 2000 F	150	190	144	130
Impact Str, Charpy (keyhole notch) ft-lb: Water quenched from 2000 F	75	30	46 (Izod V notch)	70
THERMAL TREATMENT				
Quenching Temp, F	2000–2100 water, oil or air quench	2000–2100 water, oil or air quench	2000–2150 water, oil or air quench	1950–2050 water, oil or air quench
FABRICATING PROPERTIES				
Casting	Section thicknesses from 3/16 in. up can be cast satisfactorily. Somewhat lighter sections are also possible on some parts. Good castability permits designs involving intricate shapes but drastic changes in section should be avoided			
Weldability	Can be welded by metal arc, inert gas arc, and oxyactylene gas methods. Metal arc welding most used. Oxyacetylene welding not advisable because of possible reduction in corrosion resistance resulting from carbon pick-up. Preheating not necessary but castings should be quenched from 2000 to 2100 F to restore maximum corrosion resistance			Can be welded by metal arc, inert gas arc and oxyacetylene gas methods. Metal arc welding most used. Oxyacetylene welding not advisable for reasons given before. Preheating at 400 F necessary. After welding, castings should be quenched from 2000 F
CORROSION RESISTANCE	Similar to but somewhat inferior to CF-8	Resistant to hot dilute sulfuric acid: superior to CF-8 in certain media	Similar to CH-20 but improved resistance at elevated temp	Resistant to sulfuric acid and many reducing chemicals. Good resistance to dilute hydrochloric acid and salt solutions
USES	Bearings, bushings, fittings, pump and machinery parts	Digester fittings, roasting equipment, valves, pump parts	Digesters, filter press parts, fittings, jet engine parts, pumps valves	Filter parts, heat exchanger parts, pickling rolls, hooks and racks, tanks, valve parts

NOTES:
[a] *After heat treatment.*

Compiled from data sheets of the Alloy Casting Institute

New Low-Cost Silicate Coatings

■ Development of a series of silicate coatings for all ferrous metals, which can be applied at room temperature, mature at below 1250 F, and can provide protection against weather and many kinds of corrosion, has been announced by Allied Porcenell, Inc. The coatings are intended primarily as protective finishes for sheet steel, but they can be applied to other ferrous metals, including malleable and cast iron. They can be applied in one coat for normal corrosion service; two coats are recommended for severe corrosive conditions.

Coatings' features

The new coating is applied in coatings of about 0.002 to 0.004 in. thickness. A typical single coat might be about 0.0015 in. thick. A refined natural silicate, it can be fused at temperatures of 900 to 1250 F, thus staying below the lower critical point of steel. The finish features:

Low cost. Low cost of the raw material, thin coatings that are effective, and low temperature of application add up to a low cost protective film. It is priced competitively with galvanizing. The material is roughly 1½¢ per sq ft per coat without consideration of overspray and other production losses.

Excellent corrosion resistance. Test runs in the salt spray bath of 1000 hr are reported, with no deterioration at end of run. An acid-resistant second coat is available which will meet PEI Class "A" specifications.

Good dielectric strength. The silicate coating is a good insulator even in the thin films used.

Good mechanical strength. It has much better abrasion resistance, scratch resistance, and heat resistance up to its softening temperature than any organic coatings offered for these uses, and exhibits better adherence and chip resistance than conventional porcelain enamel.

Good workability. Coated sheet steels may be punched, drilled, sawed or nailed. Light-gage sheet steel coated with the silicate coating may be cut with ordinary sheet metal shears, but torch patching of edges is necessary to reconstitute its weather protecting properties over the exposed metal edge. The material cannot be drawn or severely formed.

Versatility. Whereas special enameling grades of steel have been necessary for use with conventional porcelain enamels, the

Why They Were Developed

The new finishes are the result of more than 15 years of work by facilities now organized as Vitreco, Inc., and jointly owned by Poor & Company, Chicago, and Youngstown Sheet and Tube Co., Youngstown, Ohio. They are intended to put sheet steel back into many of the fields it has been losing to light metals and to plastics. This loss has been so great that, of the 6,000,000 to 7,000,000 tons of steel that would previously have been used for galvanized sheet in a normal year only about 2,800,000 tons were sold last year. The loss represents largely the invasion of sheet aluminum into the building and other fields.

Manufacturing capacity for the frit is now available in three plants to the extent of about 1,000,000 lb per week. While the coatings have just been announced, early versions of the silicates have been field tested for as long as 15 years.

for Ferrous Metals

by **Kenneth Rose,** *Midwestern Editor, Materials & Methods*

silicate coatings can be used without elaborate preparation on ferrous metal, including ordinary cast iron, malleable iron, black iron, and high carbon steel. There have been indications that application to other base metals may be feasible.

Variety of finishes. A range of colors comparable to the practically unlimited range of the vitrified enamels is possible. Several unusual textures, including a suede finish, are to be introduced soon.

Ease of application. The finishes may be applied without special preparation of the surface other than cleaning. This may consist of sandblasting or pickling. Sandblasting is recommended with high carbon steels, wrought iron, cast iron, or malleable iron. The frit is made into a slurry with water and applied in the manner usual for vitrified enamels. Electrostatic spraying has shown good results. Overspray may be reclaimed in the same manner as with porcelain enamels.

Firing may be done in almost any furnace capable of reaching a temperature of 1100 F, with some types of Porcenells. Less than 5 min at temperature is required to vitrify the coating, and this temperature need be reached by only the coating—a point of importance in application to heavy pieces.

Where unusual corrosion resistance or special decorative effects are required, two coats are recommended. The first, or base coat, might be fired at about 1100 F, and a second coat, of an acid-resisting type or of special color, applied over it and fired in accordance with usual procedure. Reds and yellows, for example, tend to be reduced to grays in contact with the base metal, and these require two coats. The inspection standards to be met and the corrosion resistance required will determine the coating needed.

Applications

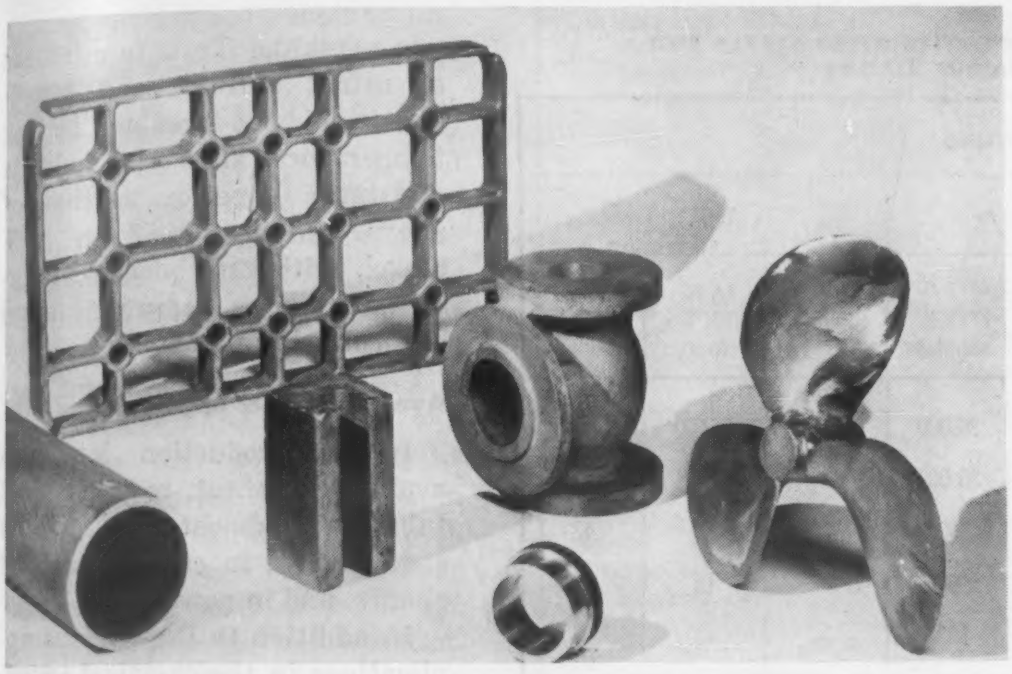
The new coatings are initially intended for the galvanized steel field, as industrial or architectural finishes. They are suitable for many of the present applications of vitrified enamels, such as in the domestic appliance field, except when high reflectivity is demanded. Reflectivity of these porcelain enamels is about 82%, whereas silicate coatings show only about 75% reflectivity.

The oil fields have experienced considerable difficulty in crude oil storage, due to attack of steel tanks by sulfur-bearing crudes. In the Oklahoma area, failures occurred within about six months. Steels with the new coatings are now being used for this purpose, and while they have not been used long enough to establish the service life of the coating, it is known that they will exceed the life of the former materials. Tests with hydrogen sulfide in controlled acidity have shown no tendency to breakdown by the silicate coatings.

Chalkboards, marine lighting fixtures, marine horns, and other appliances are now being made with silicate coated steel. The coating's high dielectric strength is important in transformer cases and pole line hardware.

Domestic appliance applications include air condition unit housings and refrigerator parts. Architectural uses include many kinds of structural and decorative panels. It is also being considered for the inside and outside coating of pipe, both wrought iron and cast iron.

New Materials, Parts and Finishes | and related equipment



New Alloy Steels

have high corrosion resistance, good high temperature strength and reduced alloying elements.

A new series of austenitic, non-magnetic steels have been developed with high resistance to a variety of acids and other corrosive media. Called Super Rustfree (SR) Steels, the alloys contain nickel, chromium, copper and molybdenum with a balance of iron always in excess of 50%. With a total alloy content less than 50%, use of critical alloying materials is kept to a minimum. The steels fall between the 18:8 type stainless and the superalloys in strength and price, though their corrosion resistance is said to be superior to both.

Developed by Uniworld Research Corp. of America, the first licensed distributor for the alloys is *Eastern Brass & Copper Co., Inc.*, 1122 E. 180th St., New York 60. Comparative corrosion and mechanical strength data are shown in two accompanying tables. The yield-to-tensile strength ratio of the currently available wrought alloy, SR 11A-1132, (75,000:95,000 psi) is higher than that of 18:8 stainless types (40,000:80,000 psi), and the elongation and reduction-in-area values of both alloys rank in about the same range, i.e., 50 and 60% respectively.

SR Steels are fully austenitic, non-magnetic in structure. The 11-A-1132 alloy has been drawn to 0.004-in. diameter wire with a 300,000-psi tensile strength. In the hard drawn condition the wrought alloy retains its austenitic, non-magnetic structure. Cast alloys become slightly magnetic after severe cold working.

Corrosion resistance

In addition to data presented in the table, corrosion tests carried out in different concentrations of sulfuric acid at room and elevated temperatures show a corrosion rate of less than 0.004 in. per year at room temperature, and less than 0.042 in. per year at boiling temperatures. SR alloys are also said to have better corrosion resistance than nickel-silver, and copper-base alloys against such media as saltspray, sodium hypochlorite and hydro-

COMPARATIVE CORROSION LOSS DATA FOR SR STEELS VS TWO REPRESENTATIVE STEELS[a]
(Miligrams/Sq Decimeter/Day)

	Loss in 13% sulfuric acid salt solution 180 F	Loss in 18% nitric acid solution R. T.	Loss in 18% nitric acid solution 160 F	Loss in 4% hydro-fluoric-6% nitric solution 110 F
65 Ni, 30% Mo, bal. iron	52.5	533.3	completely dissolved[b]	completely dissolved[b]
52 Ni, 23 Cr, 4 Mo, 6 Cu, 2% W, bal. iron	31.7	1.05	5.45	25.0
(SR Steel) 14 Ni, 12 Cr, 6.5 Cu, 6.5% Mo, bal. iron	21.7	0.42	2.43	21.66

[a] *Test carried out for 6 days.*
[b] *Samples were destroyed after 6 days.*

New Materials, Parts and Finishes | and related equipment

COMPARATIVE MECHANICAL PROPERTIES OF SR STEELS AND OTHER REPRESENTATIVE ALLOYS

	Wrought, Annealed					
	Room Temperature			1500 F		
	SR 11A-1132	65 Ni, 30% Mo, rem iron	18:8 stainless	SR 11A-1132	65 Ni, 30% Mo, rem iron	18:8 stainless
Tensile Str, psi	95,000	140,000	80,000	33,000	60,000	27,000
Yield Str, 0.2% offset, psi	75,000	65,000	30,000	—	—	16,000
Elongation in 2 in., %	50	45	50	—	12	42
Reduction in Area, %	65	45	60	—	15	60
Hardness, Brinell	—	235	180	—	—	—
	As-Cast					
	Room Temperature			1600 F		
Tensile Str, psi	112,000	82,000	70,000	33,800	58,000	16,000
Yield Str, 0.2% offset, psi	44,000	57,000	28,000	—	—	11,000
Elongation in 2 in., %	23	9	30	11	19	16
Reduction in Area, %	16	13	—	17	18	39
Hardness, Brinell	200	230	168	—	—	—

gen peroxide. Tests in mixtures of nitric, sulfuric and hydrofluoric acids at room and boiling temperatures are said to indicate resistance superior to that of alloys containing 52 to 56% nickel, with molybdenum, tungsten, chromium, copper, titanium and columbium contents.

Availability & applications

Initial production lots are available in sheet, rod, wire and tubing to almost any desired specification, in cast and forged shapes, and in powder.

In addition to the obvious applications in the chemical industries, SR Steels are said to be suitable for use in pickling tanks and equipment; components for jet propulsion, turbocompressors, gas and steam turbines; ship propellers; pumps; heat exchangers; valves; fittings; fume ducts and many uses in the food processing industry. Expected applications are to be found in the atomic energy field, and in maintenance, repair and replacement.

Aluminized Steel for Corrosion Protection

An aluminum-coated steel has been developed to combine the corrosion resisting and heat reflecting qualities of aluminum with the strength of steel. A product of *Armco Steel Corp.*, Middletown, Ohio, Aluminized Steel (Type 2) is said to provide the same resistance to atmospheric exposure as solid aluminum. Aluminized Steel (Type 1), the company's first aluminum-coated steel, was designed for high temperature and heat reflecting applications only. According to the company, Type 2 is superior to zinc-coated steel for rust protection.

The aluminum coating is said to withstand temperatures up to 900 F with no change, and up to 1250 F without serious damage. Type 2 Aluminized has the same degree of radiant heat reflectivity as aluminum and the coefficient of expansion is one half that of aluminum. It is not recommended for drawing operations; however, according to the company, it has withstood other types of severe forming without peeling or flaking of the coating. Type 2 can be welded by any conventional method, though a satisfactory soldering method is still under development.

Cost per square foot is said to be lower than aluminum of equal thickness. Greater economies are possible since the strength of the steel base permits lighter gage material to be used.

Silicone-Modified Insulating Varnish

A modified silicone dipping and impregnating varnish has been developed with dielectric properties which fall between conventional Class B organic varnishes and highly specialized dielectric coatings. It is recommended for those applications where a combination of thermal stability and resistance to oils and solvents is required.

Developed by *Dow Corning Corp.*, Midland, Mich., Sylkyd 1400 Varnish is said to have an insulating life expectancy of 25 to 50 times that of good organic varnishes at the Class B hottest temperature of 250 F. Though not intended for use at Class H temperature, the coating will stand up for short periods at temperatures of 350 to 400 F. High bond strength, coupled with good solvent and oil resistance indicates its suitability for applications such as impregnation of armatures, heavy duty motors and dry type transformers.

The material is supplied as a 40% resin solids solution at a viscosity of 400 to 800 cps. It dries in 1 hr at 300 F and cures in 10 to 12 hr at 300 F. For maximum bond strength and solvent and oil resistance a cure of 2 to 4 hr at 400 F is recommended.

TYPICAL PROPERTIES[a] OF SYLKYD 1400 VARNISH FILMS

Heat Endurance (Determined on aluminum panels):	
Flex Life, hr, at 400 F	1000
at 475 F	150
Craze Life, hr, at 400 F	2000
at 475 F	800
Weight Loss, %, 3 hr at 475 F	13
Solvent and Oil Resistance:	
Graham-Linton Hardness, gm	2000
after 1 hr immersion in xylene	
samples cured 16 hr at 300 F	500
samples cured 4 hr at 400 F	2000
after 24 hr immersion at 225 F in ASTM No. 3 oil,	
samples cured 16 hr at 300 F	2000
samples cured 2 hr at 400 F	2000
Water Absorption, %	
after 168 hr immersion at 75 F	0.95
Dielectric Strength[b], v/mil, ¼ in. electrodes:	
Condition C-96/25/50	2130
Condition C-96/25/96	1450
Dissipation Factor[b] at 75 F:	
at 60 cycles, Condition C-96/25/50	0.008
Condition C-96/25/96	0.055
at 10^5 cycles, Condition C-96/25/50	0.002
Condition C-96/25/96	0.035
Dielectric Constant[b] at 75 F:	
at 60 cycles, Condition C-96/25/50	3.43
Condition C-96/25/96	4.48
at 10^5 cycles, Condition C-96/25/50	3.40
Condition C-96/25/96	3.70
Thermal Life[c], hr:	
at 575 F	35
at 525 F	140
at 480 F	750
at 430 F	2200

[a] *Properties measured in accordance with ASTM methods on varnish films cured 16 hr at 300 F unless otherwise indicated.*
[b] *Electrical properties measured on varnish coated glass fibers cured 16 hr at 300 F.*
[c] *Hours aging, at temperature necessary to reduce the dielectric strength of glass cloth impregnated with Sylkyd 1400 to 200 v/mil. ASTM Special Technical Publication No. 161 "A Method of Evaluation of the Thermal Stability of Flexible Sheet Insulation", R. M. Plettner and C. G. Currin.*

New Wire Insulation Withstands Higher Temperatures

A new thin-film wire insulation which resists temperatures of 300 F is expected to permit higher horsepower motors without increasing their size. Called Alkanex, the material is said to combine physical and chemical properties needed in thin-film motor insulation. It can be applied with standard enameling equipment.

Developed by *General Electric Co.'s Research Laboratories*, Schenectady, N. Y., Alkanex is said to permit smaller motors with higher horsepower ratings by replacing the bulky insulation heretofore needed to resist temperatures above 220 F. According to tests at G-E, Alkanex showed no deterioration or loss of insulating strength after baking for more than 6 mo at 300 F. Tests at higher temperatures indicate a life of several years at 300 F.

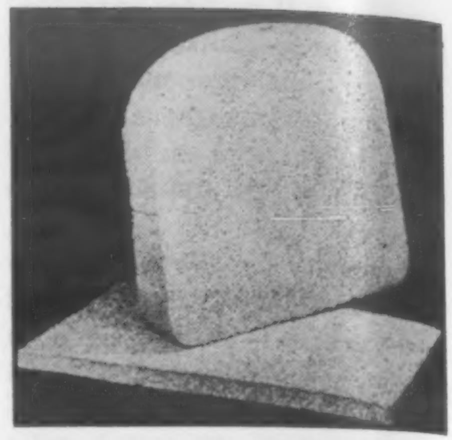
The material is said to have good resistance to abrasion and solvents. The pulling, bending and flexing of wire during construction of a motor puts sever strains on the enamel as well a the wire. In experiments wi h Alkanex the coated wire has been pounded flat without breaking the organic film.

***Insulation** shown on test wires withstands temperatures of 300 F.*

New Materials, Parts and Finishes

and related equipment

Low Cost Foam Rubber Shapes



Foam rubber *is available in ed shapes, slabs and sheets.*

Latex-bonded virgin foam rubber padding is now available at approximately 1/3 the usual cost of foam rubber from *Adsco Molded Products Co., div. of Greenwood Packaging Supply Co.*, 859-870 Summer Ave., Newark, N. J. The material, called Bond-Foam, is said to posses high resiliency, durability and lightness of weight. Bond-Foam is available in several stock size mold patterns, slabs and in sheet thicknesses from $\frac{3}{8}$ to 4 in. in the following standard sizes: 17 x 32, 24 x 36, 37 x 74, 23½ x 47½, 18¼ x 37, 37 x 61, 18½ x 47 in.

It is possible for the sheets to be cut to suit specific applications.

General Purpose Foamed-In-Place Plastics

A series of foamed-in-place isocyanate plastics with densities ranging from 2 to 20 lb per cu ft is being produced by the *Atlas Mineral Products Co.*, Mertztown, Pa. under a licensing agreement with Du Pont. Called Urefoam, the materials are available as two-package units which can be mixed and poured to the desired densities on the job. Rigid and semi-rigid types are presently available. Resilient and highly flexible types are under development. The table shows some typical mechanical properties of the four standard products available.

General physical properties

Specific properties of foams will vary with formulations. Thermal conductivity "K" values of 0.25-0.30 Btu/sq ft/hr/°F/in. at 70 F are obtained with low density varieties. Preliminary electrical tests on expanded Urefoam R-02 indicate a dielectric constant (1000 cycles) of 1.42 and a power factor (1000 cycles) of 0.003. According to the producers, electrical properties of the foams suggest applications such as potting electrical components and fabrication of radomes.

The foams are said to develop bond strengths greater than the strength of the foam when joined to glass, metals, wood, ceramics and most plastics. They will not adhere to polyethylene, the fluorocarbons, paraffin, or wax. Water absorption is dependent on cell structure. Rigid types of foams, having mostly closed cells possess the lowest absorption values.

Urefoam R series is recommended for continuous service up to 212 F and for intermittent use up to 250 F. At higher temperatures foams will soften and shrink. They are resistant to oils, grease and hydrocarbon solvents such as hydraulic fluids and gasoline. The materials will not readily support combustion and are said to be completely resistant to mildew and other molds. They are also resistant to weak acids, alkalies and all neutral salts. On exposure to sunlight, expanded foams darken, but no appreciable effect on physical properties has been noted.

Applications

The foams are said to be particularly well suited for use as light-weight structural materials and low temperature insulation. The foam-in-place characteristic offers obvious economies in forming. The low thermal conductivity of the material, coupled with the light-weight factor permit its advantageous use as insulation for structures, piping, valves, pumps and other items of plant equipment. ***(See Polyester-Isocyanate article in this issue.)***

TYPICAL MECHANICAL PROPERTIES OF FOUR STANDARD UREFOAMS

	R-02 (Density: 2–3 lb/cu ft)	R-07 (Density: 6–8 lb/cu ft)	R-12 (Density: 11–13 lb/cu ft)	R-19 (Density: 18–20 lb/cu ft)
Ten Str at 77 F, psi*	25	150	275	450
Comp Str at 77 F (Stress to produce 10% deflection), psi	4.6	150	250	475
(Stress to produce 50% deflection), psi	6.0	200	350	750

* *Test specimens were 1.13 in. in diameter (1.00 sq in. area) and 1.0 in. thick. All molded surfaces were removed from the specimens before cementing to metal blocks with a neoprene cement.*

(More New Materials on page 152)

New Materials, Parts, Finishes

Blue Asbestos Fiber

A new method of extraction, grading and quality control is said to be responsible for providing Transvaal blue asbestos with 1) uniform fibers, requiring no further processing; 2) minimum dust and grit, not exceeding 3%; and 3) rigid quality specifications. Marketed by *Pitnam Industrial Products Co.*, 608 Fifth Ave., New York 20, the fiber is said to be extracted from high grade ore by a technique which preserves the inherent characteristics of the original fiber.

According to the company, Pitnam Transvaal Blue (crocidolite) is free from talc, has high specific volume, permeability, tensile strength and elasticity. It requires no further processing and only one pass through a disintegrator to re-establish specification volume after packing and shipping. It is said to be particularly well suited for blending with short fiber crysotile.

Ceramic-Base Coating Protects Water Tanks

A ceramic base material, Expansolin, which will contract or expand with the iron or steel to which it is bonded has been developed by *Emjay Maintenance Engineers*, 327 Union Ave., Rutherford, N. J. It is designed to protect new or old water tanks from corrosion, contamination, and sludge and lime build-up over a temperature range of 34 to 230 F. The protective lining should be applied in 1/4-in. thicknesses and is suitable for hot or cold water tanks.

Neoprene Coating

A one-component protective coating, Neoprene W, has been marketed by *Carboline Co.*, 331 Thornton Ave., St. Louis 19, Mo. No catalysts or accelerators are required for application. Two

New Materials, Parts, Finishes

coats of Neoprene W are applied by brush or spray over one coat of Neoprene W Primer for a thickness of 8 mils on either flat or vertical surfaces. Drying time between coats is approximately 2 to 3 hr, and in most cases the coated surface is said to be serviceable after 24 hr. Curing takes place at room temperature.

The coating is recommended for protection against most acid and alkali fumes and splash, high humidity, abrasion and weathering. Worn or damaged areas can be recoated and the resulting bond is said to be as strong as the original coating.

With a coverage of 420 mil-ft per gal (140 sq ft—3-mil film), Neoprene W is designed for use as a maintenance paint in chemical processing plants, water treatment and sewage plants, pulp and paper mills, food processing, and marine maintenance.

New Polymer Improves Baking Enamels

Melamine formaldehyde resins are used in baking enamels to provide a fast cure, high gloss, film hardness and resistance to deterioration. A new melamine formaldehyde polymer, Uformite MM-47, produced by *Rohm & Haas Co.,* Washington Square, Philadelphia 5, is said to provide industrial baking enamels with wide compatibility with short and medium length alkyds, high resistance to soap and alkali, good color and color retention, as well as fast cure, good hardness and high gloss properties.

Tough Steel in Commercial Plate Sizes

The new T-1 steel developed by U.S. Steel Corp. (M&M, Jan., 1955) is now being produced in every commercial plate size by *Lukens Steel Co.,* Coatesville, Pa.,

New Materials, Parts, Finishes

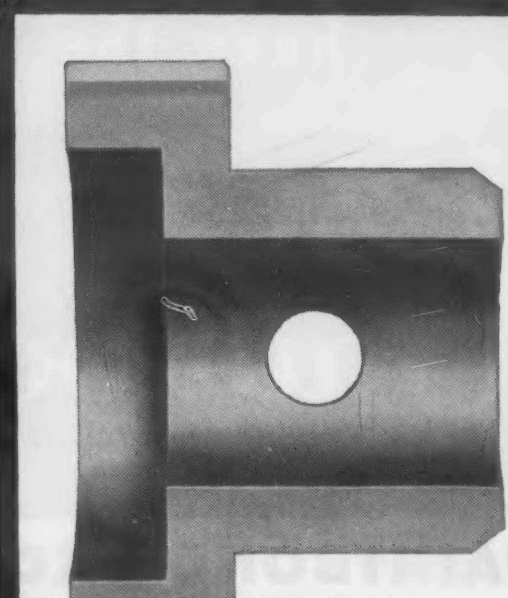
under a licensing agreement with USS. It is a quenched and tempered low-carbon steel with high yield strength, good toughness, low transition temperature, good weldability, high abrasion resistance and relatively good atmospheric corrosion resistance. Its cost is about 2½ or 3 times that of ordinary carbon steel. Though applications for the new steel have not been fully explored, initial production at Lukens is for general industrial equipment, bridges, earth-moving and construction machinery.

Plastics Tape Resists Flame and Corrosion

A flame-resistant plastics tape, which will not support combustion, has been developed for use as a seal against air loss in the joining of cold and warm air ducts and for sealing joints. The aluminum-colored tape has a vinyl plastic film backing that can withstand acids, alkalies, salt solutions, water, alcohols, and hydrocarbons such as gasoline and kerosene.

According to the manufacturer, *Minnesota Mining and Manufacturing Co.*, 900 Fauquier St., Dept. P-1631, St. Paul, Minn., "Scotch" brand plastics tape No. 474, is abrasion-resistant with good resistance to

COSTS CUT 94%



Etched cross section of part — showing .080″ hardened depth.

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Carburize	0.0200	*eliminated*	
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2nd quench	0.0150	*eliminated*	
Draw	0.0050	*eliminated (self-draw)*	
Shotblast	0.0035	*eliminated*	
Internal Grind	0.0243	*eliminated*	
External Grind	0.0166	*eliminated*	
	$0.1014		$0.0060

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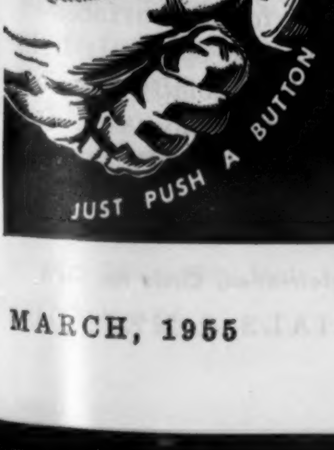

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humidity changes and moisture vapor and will not be attacked by rodents. Designed for use on round, square, or flexible metal ducts, No. 474 has good elasticity and can withstand temperatures up to 240 F.

The new tape is 3 mils thick and is available on 36-yd rolls in widths ranging from ¼ to 24 in.

Photo-Sensitized Aluminum Sheet

A photo-sensitized aluminum sheet that can be processed directly from either positive or negative, without a darkroom, has been developed by the *Anken Chemical & Film Corp.*, 9 Hix Ave., Newton, N. J.

Called Meta-Positive, the coated sheet is as dimensionally stable as the base material (0.006-in. aluminum), can be bent frequently without surface cracking, withstands moisture, prolonged sunlight or submersion in boiling water, and is impervious to extreme cold, according to the company. Special treatment of the metal is said to retard oxidation and prevent any damage to the photo emulsions by the aluminum.

Available in 32-in. wide rolls of any length, Meta-Positive is designed for use in making templates, aircraft and automobile instrument panels, printing and pictorial treatment of identification labels, panels or tags, instrument gages, heavy machinery and power tools.

Aluminum Toughens Strippable Coating

A new aluminum-pigmented strippable coating, which may be applied to metal surfaces by either brush or spray, is being marketed by *Specialty Coatings, Inc.*, 1085 Allegheny Ave., Oakmont, Pa. Called PV-845, the

◀ For more information, Circle No. 374

New Materials, Parts, Finishes

coating requires no surface preparation and, when stripped off, leaves no greasy residue.

According to the company, the aluminum pigment adds surface roughness to the coating and assists in preventing moisture transmission. PV-845 is said to be useful for 1) protecting all types of metals during both inside and short-term outside storage; 2) protecting polished surfaces from marring and scratching; 3) coating idle tools and dies; 4) protection against die marks during stamping operations; 5) providing a removable film on inner surfaces of spray booths; and 6) as a web coating to completely enclose bulky objects.

Drying time of the coating depends on the thickness of the coat. A film 3 mils thick, sufficient to provide adequate strength for stripping, will dry enough to handle in 5 to 10 min under average temperature and humidity conditions. PV-845 is available in 1, 5, and 55-gal drums.

Vinyl-Metal Laminate Produced in Coil Form

The vinyl-metal laminate developed by U. S. Rubber Co. (M&M Sept., 1953) is now being produced in coil form in commercial coil gages by *Enamelstrip Corp.*, Allentown, Pa. Present maximum width is 20 in.; a 30-in. maximum is expected in the future. Called Marvibond, the vinyl laminate is available in steel or aluminum. All colors are being produced with various embossed or grained finishes. It can be furnished with vinyl sheeting on one or both sides, or vinyl sheeting on one side and a baked finish on the other. The coil form permits obvious production advantages, such as automatic feed, progressive dies, lower labor costs, less scrap loss, lower handling costs, etc.

The laminate can be deep

For more information, Circle No. 373 ➤

drawn, sheared, crimped, bent, embossed, drilled, roll formed and punched, using standard tools, without damage to the vinyl or the bond. The plastics will not chip, crack, craze or flake off. The laminated vinyl possesses the normal properties of the plastics such as corrosion and chemical resistance and will resist temperatures up to 250 F.

New Powder Speeds De-plating of Metals

A new powder has been developed to speed acid action in stripping defective plate from copper without injuring the base metal. According to the producer, *Enthone, Inc.*, 442 Elm St., New Haven, Conn., the powder, when added to stripping acids, rapidly dissolves defective chromium, nickel and other plates, leaving the copper base-metal clean and ready for refinishing.

The new de-plating powder is finding applications in the manufacture of radio and electronic equipment, household appliances, cameras, office and business machinery and automobile parts.

The powder is being marketed with another Enthone powder designed for stripping defective plates from steel. They are being sold under the trade names Enstrips "S" and 165S.

New Metal-Joining Materials

Recently several companies have announced the development of new materials for welding and brazing a variety of metals. These include electrodes for welding cast iron, cast iron to steel, carbon steel, high alloy steel, and phosphor bronze; electrodes for hard-facing, for under-water cutting and welding; a low hydrogen electrode with

New Materials, Parts, Finishes

iron powder in the coating; and silver brazing alloys and fluxes.

Rod for cast iron

A low-cost, nonmachinable cast iron electrode, said to have high as-welded strength has been developed by *All-State Welding Alloys Co., Inc.*, 249-55 Ferris Ave., White Plains, N. Y. It is primarily intended for repair and reclamation where the finish may be ground or left as-welded. Designated All-State No. 6 High Strength Cast Iron Electrode, the electrode can be applied with a.c. or d.c. welders. Tensile strength of deposits is said to be 60,000 psi. According to the company, the rod produces sound welds with a minimum of scatter loss. It is available in 3/32-, 1/8-, and 5/32-in. core sizes.

Welds iron to mild steel

An electrode with a bi-metallic core of copper and mild steel, with arc-shielding flux coating, has been developed for welding steel to cast iron. Marketed by *C. E. Phillips & Co.*, 2750 Poplar St., Detroit 8, the Phillips 100-X Electrode can be used with a.c. or d.c. current and is said to provide a fast smooth arc. Deposits are said to have a much higher tensile strength than that of cast iron, and to be tough, ductile and resistant to shock. The rods are intended for repair welding on all grades of iron castings, welding cast iron to carbon and alloy steels, and welding copper to cast iron. They are not suitable where the deposit must be machined at the line of fusion. The 100-X electrodes are available in 1/8-, 5/32-, and 3/16-in. sizes.

Electrode for carbon steels

A new contact-arc gap electrode for welding carbon steel has been marketed by *Eutectic Welding Alloys Corp.*, 40-40 172 St., Flushing, N. Y. Called Eutec-HandOmatic #2, the rod can be operated on a.c. or d.c.

New Materials, Parts, Finishes

and is said to successfully weld steel in thicknesses of 1/8, 3/16, and 1/4 in. without burn-through, as well as the heavier 3/8- to 3/4-in. material.

Welding high alloy steels

A non-heat-treatable electrode, deposits from which are said to be work-hardenable to over 180,000 psi has been developed for welding high alloy steels. Called All-State No. 275 Chrome-Nickel, the electrode produces deposits which maintain strength at high temperatures, according to the producers, *All-State Welding Alloys Co., Inc.*, 249-55 Ferris Ave., White Plains, N. Y. Deposits are said to have high corrosion resistance, hardness and wear resistance. As-welded properties include a tensile strength of 120,000 psi, elongation in 2 in. of 25%, and a 200 Brinell hardness. It is recommended for use with high alloy steels, tool steels, spring steels, pressure vessels, mild and medium carbon steels and air-hardenable steels. It is available in 3/32-, 1/8-, 5/32- and 3/16-in. core sizes.

Joins Phosphor-Bronze

A new phosphor-bronze electrode has been developed for overlay work and general maintenance and repair welding. It can be used in all positions, will weld dissimilar metals such as cast iron, bronze, brass, etc., has a high deposition rate and provides sound deposits, according to the manufacturer, *Ampco Metal, Inc.*, Dept. WR-6, Milwaukee 46. The core wire is a phosphor bronze grade C alloy and the coating contains a grain refining and deoxidizing ingredient. Other features claimed for deposits are fine grain, resulting in higher mechanical properties; smoother arc action and burn-off; and smoother beads with practically no undercutting, pit-

New Materials, Parts, Finishes

ting or porosity. Called Phos-Trode, the rods are available in 6 sizes from 3/32 to ¼ in.

Hard Facing Rod

Mir-O-Col No. 2, a new hard facing electrode, is particularly recommended for rebuilding heavy-duty equipment where severe impact and abrasion are encountered. Features of the rod are said to include an improved flux coating, rapid burn-off rate, porosity-free deposits and smoother flowing characteristics. It is marketed by *Mir-O-Col Alloy Co., Inc.*, 312 North Ave. 21, Los Angeles 31, Calif. It can be applied in single narrow beads or heavy weave passes up to ¾ in. in depth without chipping, spalling or breaking at the bond. Deposits are said to bond equally well with either the parent metal or other hard-facing deposits, to have high red-hardness valves and to be forgeable at red heat, but not machinable. Rockwell hardness is 54 to 57 on the C scale.

Rods cut and weld under water

Two new electrodes for underwater work, Pacific UC for cutting and Pacific UW for welding have been marketed by *Pacific Welding Alloys Mfg. Co.*, 310 North Ave., Los Angeles 21, Calif. The UC rod is a steel tube, 14 in. long with a 5/16-in. o.d. and a 0.112-in i.d.; it has an extruded flux coating which makes it waterproof. Oxygen is delivered through the bore while the arc is maintained to provide a puddle of molten metal which is oxidized and pierced by the jet of oxygen. It is said to be simple to operate and not subject to breakage. The UW welding electrode is steel with an extruded waterproofed coating developed for underwater welding. In operation it produces a gaseous shield around the arc which excludes water while weld metal is deposited. UC rods are available in 5/16-in. sizes only,

Only 4 SECONDS to make this oil and air-tight joint with *EASY-FLO 45*

EASY-FLO 45 WIRE RING

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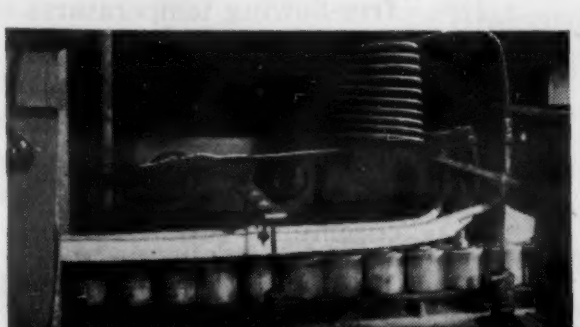
The unit is a pressure switch which is part of the Studebaker anti-creep "hill-holding" device. The job is brazing the threaded spud into the cover. Operator sets covers in cylindrical holders on an endless chain and in the covers she places the spuds, each one with a ring of EASY-FLO 45 preplaced. Assemblies pass thru an induction heating coil (left) — 14 a minute.



Photos and data courtesy of FASCO Industries, Inc., Rochester, N.Y.

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while the UW rods are available in 1/8-, 5/32-, and 3/16-in. sizes.

Low hydrogen electrode

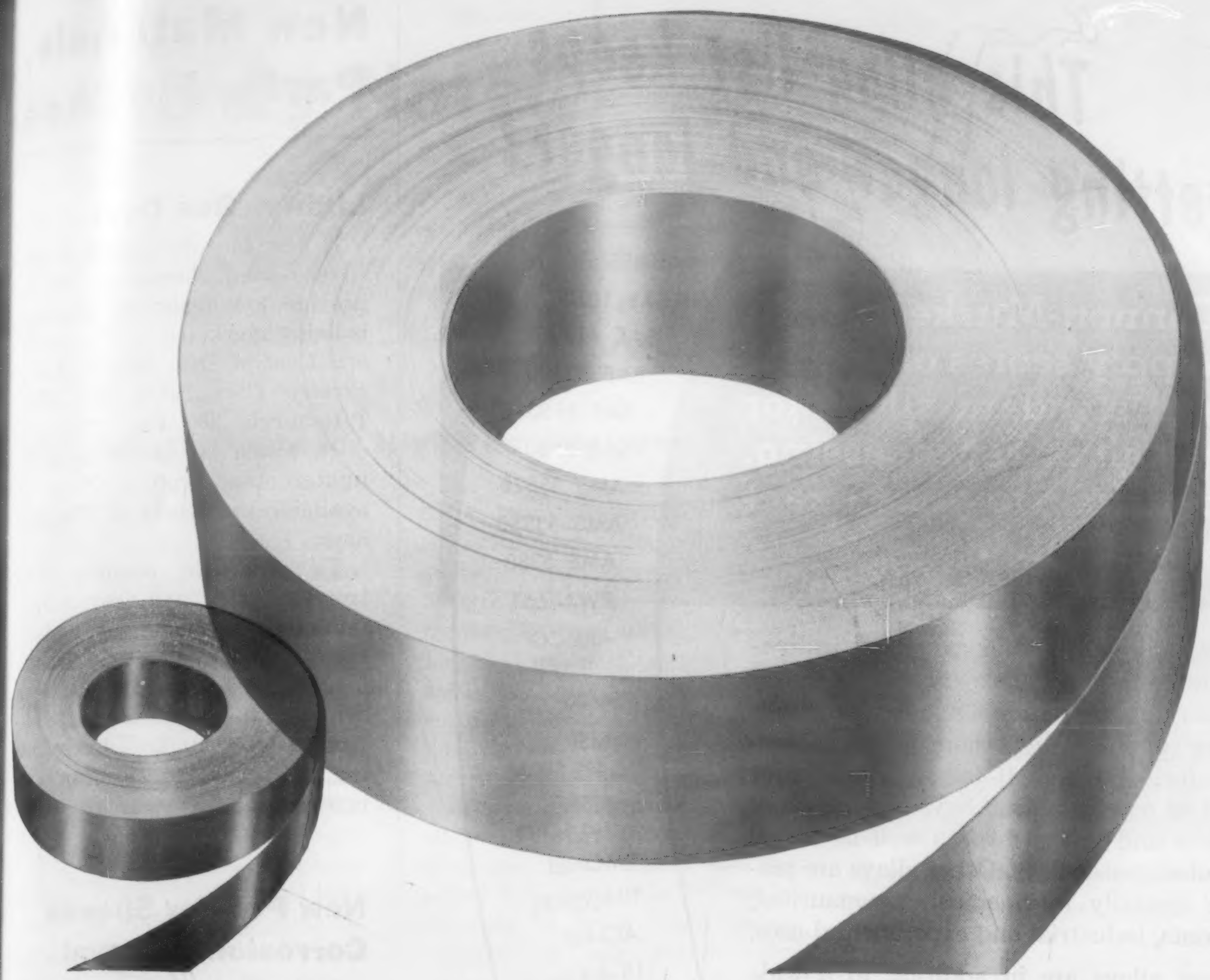
A low hydrogen electrode has been marketed which contains iron powder in the coating, thus allowing high welding currents and faster deposition. Developed by *Alloy Rods Co.*, Lincoln Highway West, York, Pa., the Atom-Arc is available in the strength levels of 7016, 8016, 9016, 10016 and 12016 AWS grades. Use of the new rods is said to eliminate starting porosity common to low hydrogen electrodes, and to provide deposits with Charpy v-notch impact values up to 178 ft-lb. Atom-Arc rods can be used with either a.c. or d.c. reverse polarity.

Silver brazing materials

Two companies have recently marketed silver brazing alloys. A new line of silver brazing alloys and flux for all types of production jobs are available in rod, wire, sheet, rings and gaskets, as well as special shapes from the *Air Reduction Sales Co.*, 60 E. 42nd St., New York 17. The line of Aircosil Alloys and Flux are said to provide strong joints, and the penetrating action is said to be fast with small, neat fillets. The materials are said to join practically all metals that have melting points above the free-flowing temperatures of the brazing alloys.

A silver brazing alloy developed particularly to overcome crevice corrosion problems in brazing the 400 series straight chromium stainless steels has been developed by *Handy & Harman*, 82 Fulton St., New York 38. Known as RSNI, the alloy contains 63.0 silver, 28.5 copper, 6.0 tin and 2.5% nickel. It melts at 1325 F and flows at 1475 F. It does not flatten out at brazing temperatures to form thin fillet edges. It is available in wire of any standard gage.

(More New Materials on page 170)



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New Materials, Parts, Finishes

Lighter Bus Duct

A new bus duct, with double silver-coated aluminum bars to provide low resistance contacts is being marketed by the *Standard Control Div., Westinghouse Electric Corp.*, P.O. Box 2099, Pittsburgh 30, Pa. The new duct, which is said to be 35% lighter than copper duct, is available in ratings of 225-4000 amps.

To eliminate possible electrolytic action and provide better adhesion of the silver plate, the aluminum bar is put through a 12-step process. It includes an acid and a zincate dip, in addition to the strike, electroplating, and various cleaning and rinsing steps.

New Powder Speeds Corrosion Removal

A new rust remover available in powder form has been developed for removing corrosion from ferrous and nonferrous metals. The powder is mixed with water before use and is said to be nontoxic and nonflammable. The cleaned surface is said to retain a corrosion-resistant film which forms a base for any further coating or plating.

The powder, produced by the *By-Buk Co.*, 4314 W. Pico Blvd., Los Angeles 19, Calif., removes rust and corrosion in 10 min to 3 hr, depending on the amount. When used as a hot bath, the action may be completed in 2 sec to 10 min, according to the company. The preventive film will protect metal for several weeks or months, depending on the atmospheric conditions. According to the producers, removal is more rapid on nonferrous metals. A thickening agent may be added to the liquid solution for use on vertical surfaces and large objects which cannot be submerged in a bath.

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A digest of papers, articles, reports and books of current interest to those in the materials field.

This Month:

- *Powder metallurgy*
- *Controlling residual stresses*
- *Testing vinyl films*
- *Hard vs soft jet blades*
- *Harder cermets*

Metal Powder Parts for High Temperature Use

At present, powder metallurgy technology seems to hold high promise for solving problems of high temperature materials. Ideally, designers would prefer materials with a higher use temperature than is presently possible with the super alloys, with no sacrifice in ductility. Powder metallurgy would seem to offer at least two approaches to this ideal: 1) production of stronger parts having controlled microstructure without the usual limitations in quantities of alloying additions; and 2) sintered aluminum powder uses a mechanism for increasing limiting temperatures that may be applicable to other alloy systems. In a paper published in the November issue of the *Journal of Metals* last year, G. M. Ault and G. C. Deutsch of the Lewis Flight Propulsion Lab reviewed various efforts in the field of powder metallurgy to solve high temperature problems. They discussed sintered super alloys, sintered aluminum powder, porous materials for transpiration cooling, molybdenum, cermets, and intermetallics.

Super alloys from powder

From the standpoint of properties, the objective of the powder metallurgist has been to obtain properties comparable to those of wrought or cast parts. In studies of the powder metallurgy of the cobalt-base alloy, X-40, attempts have centered around obtaining at least equivalent properties, since many high temperature applications require superior properties. Stress-rupture properties equivalent to those of cast X-40 were obtained at 1500 F for rupture times of at least 100 hr. The hot coining method was used to form fully alloyed powders. The hot forging operation involved in hot coining serves to eliminate voids.

In wrought high temperature alloys of today the amount of alloy additions which can be added for strength is limited by inability to break down ingots because of segregation, etc. Large segregations can be avoided in the powder metal part by using prealloyed powders. Prealloyed powders and hot coining permits alloys with greater strengthening additions to be formed into shapes with a distinct strength advantage over wrought parts.

Sintered aluminum powder

Sintering aluminum powder extends the maximum use temperature of aluminum by several hundred degrees. The higher strength of the SAP compacts would seem to be directly proportional to the oxide content of the alloy. One theory holds that during hot working, the aluminum particles are plastically deformed so that their individual oxide coatings are ruptured, allowing the aluminum particles to weld together. Higher strengths are attributed to the trapped, finely dispersed oxide particles. As the oxide content increases, the distance between oxide particles tends to decrease,

***Typical root failure** of a cermet type-B turbine bucket.*

at least partially accounting for increase in strength. At 600 F, wrought sintered aluminum alloys are much stronger than cast and wrought alloys. It should also be remembered that the SAP does not contain conventional alloying elements.

The authors believe that the increase in high temperature strength produced by dispersing stable particles also holds promise for other alloy systems. Similar improvements in platinum and tungsten have been noted. The General Electric Co. of England has achieved encouraging high temperature strength and creep properties in the cobalt-base alloy, vitallium, by addition of thoria or other similar materials during powder metal fabrication.

Transpiration cooling

Though there are various methods of cooling turbine blades, the

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three general requirements for a porous blade material for transpiration cooling are 1) chemical inertness, particularly in regard to the coolant; 2) adequate strength; and 3) ability to permit passage of required amounts of coolant, or permeability. Materials for transpiration cooling are difficult to evaluate at this time since they are in a relatively early stage of development. A rough approximation of strength requirements is given by the authors as 20,000 to 25,000 psi with greater than 2% ductility at use temperatures of 900 to 1100 F.

Four methods of producing porous materials are 1) sintering loose powders; 2) sintering loose powders having a wide solidus-liquidus temperature range so that sintering is accomplished in the presence of a liquid phase; 3) sintering compacted powders; and 4) sintering compacted powders with a pore former. Two principal problems in fabrication of porous turbine blades are that present procedures do not yield reproducible permeabilities from blade to blade, and that for uniform cooling the material should have a gradation in permeability which conforms to changes in pressure of the external environment of the blade.

While porous materials appear promising from the standpoint of cooling effectiveness, all the problems have not yet been determined. There are also other fabrication methods such as using wire cloth or screen which would appear to be competitive with powder metallurgy techniques.

Molybdenum

Powder metallurgy has always been useful for fabricating high melting point metals such as molybdenum. At this point it is difficult to compare arc-cast molybdenum with that formed by powder metallurgy. The latter is equivalent to the pure arc-cast material on the basis of stress-rupture strength, though many arc-cast molybdenum alloys are far superior to the pure cast molybdenum in stress-rupture strength. All these molybdenum

Tool Steel Topics

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You Can Reduce Warpage by Supporting Tools During Heat-Treatment

Warpage of tools in heat-treatment is usually associated with the geometrical shape of the tools, or the manner in which they are supported during heating for the quench. When steels are heated in the critical range, just prior to quenching, they are weak, and if not supported properly, will sag or flow plastically.

Long tools should be supported at frequent intervals along their length. If section changes are present for appreciable lengths, the tools should be supported at each section. However, the span between supports should not exceed three times the tool diameter.

Maker of Tableware Likes Economy of Striking Die of Bearcat

r of stainless steel tableware had ng striking dies which produced runs of 19,000 pieces. Good, they but perhaps by experimenting ld find something better. So they to switch to Bethlehem Bearcat el, then watch their production The number of pieces per die right from the start.

Bearcat dies, used in working lled stainless blanks of varying s, are hardened to Rockwell . As no redressing is possible, run until failure occurs. The perintendent says: "Bearcat is phenomenal job. We particularly resistance to shock."

es shock-resistance, Bearcat is well suited for any application where good machining is essential. It is deep-hardening in air, and offers low distortion in heat-treatment. For some applications, it can be carburized easily for long wear.

TYPICAL ANALYSIS

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materials are superior to the better cast commercial super alloys.

Molybdenum and its alloys have not been widely used for structural parts due to their lack of oxidation resistance. Neither alloy additions nor coatings have been found to be completely satisfactory in protecting highly stressed components.

Cermets

Cermets were developed to combine the high temperature strength of ceramics with the ductility of metals. Various combinations have been tested, some of the most successful being titanium carbide with a nickel binder. The authors mention J. T. Norton's description of the ideal cermet structure. The ideal structure would consist of regular polyhedra surrounded by thin restrained films of metal. To this description, the authors add that improved ductility and impact strength may be gained with films thicker than those used for optimum strength, and a compromise to achieve the best combination of properties may have to be reached.

Intermetallics and hard metals

This category consists of carbides, nitrides, borides and silicides of the transition metals. They do not have a metal phase as most cermets have.

A particularly interesting intermetallic developed at the NACA is molybdenum disilicide. It has electrical conductivity approximating that of stainless steel and thermal conductivity comparable to that of nickel at room temperature. It has outstanding resistance to oxidation, and its short-time strength can be approximately doubled by increasing grain size and adding carbon with a resulting decrease in oxygen content. Other typical materials in this class are chromium carbide, and chromium titanide. All these materials have excellent high temperature strength, good resistance to oxidation and are resistant to thermal shock.

(More Contents Noted on page 176)

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Practical Control of Residual Stresses

Residual stresses remaining in metal after thermal or mechanical working are considered to be a major factor contributing to several types of service failures. On the other hand, introducing certain types of residual stresses may permit the increasing of design strength. Both types of residual stresses discussed here are the so-called macrostresses occurring over a range of 0.001 to 0.1 in. of metal thickness. In a paper delivered before the Society of Automotive Engineers' Golden Anniversary Annual Meeting in January, George Sachs, Director of Metallurgical Research, Syracuse University, discussed the general effects of residual macrostresses and their practical control to minimize service failures.

Effects and control

The effects of residual stresses primarily depend on their magnitude at exposed surfaces. As a rule, residual tensile stresses at the surface are damaging, while residual compressive stresses (such as those set up by shot peening) are beneficial. The effects of residual stresses on various strength properties are not fully recognized because of several factors, i.e., 1) they depend on the particular material and its condition; 2) they differ with the nature of applied loads and the chemical environment; 3) they are affected by such factors as overstraining, repeated loading, or localized heating of surface layers; and 4) residual-stress patterns are generally very complex and some of their unrecognized or neglected features may be decisive for the occurrence of failures.

From the standpoint of production, control measures are classified in five major categories: 1) selection of most suitable material; 2) development of processing and heat-treating methods conducive to most favorable residual-stress condition; 3) close

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control of finishing operations; 4) application of final mechanical-stress relieving treatments; and 5) stress-relief annealing.

Application of control methods

An example of residual stresses leading to failure due to a combination of mechanical load and chemical environment is the longitudinal splitting of aluminum propellors on airplanes about 10 years ago. The author diagnosed the failure as a slowly-progressing fracture due to a combination of high residual tensile stresses at the surface of the hub bore resulting from heat treating and an unknown corrosive action of oil. The condition was controlled by altering the heat treating, resulting in considerably lower stresses, and shot peening the bore surface to introduce compressive stresses in the surface.

The best known example of stress-corrosion cracking is "season cracking" of brass and copper-alloy parts which have been drawn or spun. A similar phenomenon is encountered with other materials such as carbon and low alloy steels, stainless steels and aluminum alloys. It is explained by the combination of tensile surface stresses and chemical attack by ammonia in the atmosphere. Stress-relief annealing is the control method usually applied.

The application of compressive stresses to increase fatigue life of materials include such treatments as shot peening or surface rolling. If the material can be selected, high fatigue properties of a steel part can be achieved by case hardening which induces compressive stresses in the surface. Though the effect of machining is probably insignificant in most cases, grinding can be detrimental since it heats the surface and may set up tensile stresses. With heat-treated high-strength steels the author recommends a regular check of surface hardness in order to prevent grinding damage.

The role of residual stress in performance of parts which are loaded statically or only a few

times has not been fully explored. Premature static and sustained-load failures with residual stresses being a contributing factor have been observed only under conditions conducive to stress corrosion.

Residual stresses frequently cause difficulties in production and in service of parts which require high dimensional accuracy. One solution is rough machining to almost the final dimensions, allowing the distortion to develop, then finish machining. However, in time, further distortions may develop due to the retained stresses. Either homogenous stretching (or compressing) or stress-relief annealing can entirely eliminate such stresses. Care must be taken that the change in properties of the material due to these treatments is acceptable in light of the specifications of the part.

Tensile Tests of Sprayed and Cast Vinyl Films

Variations which are found in tensile strength values of elastomers also occur in tensile test values of spray-formed vinyl films. In the January issue of *Rubber Age*, L. Berger and I. Weber of the Frankford Arsenal described results of investigations, the purposes of which were: 1) to compare the uniformity of test results of spray-formed vinyl films with those of cast films; 2) determine a possible relationship between tensile strength and film density; 3) determine the effect of varying degrees of wet to dry spray techniques in preparing the films; and 4) determine and evaluate sources of error in tensile strength determinations.

The authors found that there is no significant difference in reproducibility of tensile strength results between sprayed and cast vinyl film specimens. They also found that proper sampling can make the observed standard error of tensile strength mean

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agree more closely with the calculated standard error. A proper method of sampling both spray-formed and cast vinyl films is to select at random five specimens from each of three films of the same material prepared by one operator using the same technique. The 15 specimens are used to obtain a mean.

Tensile strength of both types of films is correlated curvilinearly in a positive direction with density. Tensile strength and density of spray-formed vinyl films increase as the spray technique is altered from wet to dry, provided the film is devoid of excessive laminations. Maximum strength and density are obtained with cast films. The wet spray technique provides optimum smoothness in spray-formed films. The authors also determined that there is a linear relationship between tensile strength and tensile index, which may vary for different formulations. For similar formulations, the relationship is reproducible.

Jet Compressor Blades —Hard or Soft?

There are many considerations which must be weighed in selecting a material for a jet engine compressor blade. Compressor blades require an extremely high degree of quality and reliability, since there are about 2000 compressor blades in the average axial flow jet engine. In a paper delivered before the Society of Automotive Engineers' Golden Anniversary Annual Meeting in January, E.M. Phillips (ret.) and R.E. Weymouth of G-E discussed the pros and cons of hard vs soft blades and explained why G-E eventually reduced the hardness of the turbine blades on their J-47 jet engine.

Fatigue strength vs damping capacity

Type 403 stainless iron (12% chromium) was selected for the blades because of its good

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fatigue strength and adequate corrosion resistance. The original blade hardness range selected was 32 to 42 Rc (upper limit of 42 was later lowered to 38 to improve machinability) in order to gain the highest possible fatigue strength.

Like most materials, the higher the hardness of 402, the higher the fatigue strength. However, data on internal damping qualities showed that type 403 has excellent damping capacity at low hardness values, but that it falls off rapidly as hardness increases. The falling off of damping capacity with increasing hardness was more rapid than the rise in fatigue strength with increased hardness. Therefore, it seemed probable that better results might be obtained by reducing blade hardness in order to obtain a correct balance of these properties, thus arriving at a maximum value of safety factor.

It was found that the factor of safety varies as the product of fatigue strength and internal damping at resonant vibration conditions. Upon further analysis it appeared that the increase in damping capacity gave more structural advantage than the loss due to lower fatigue strength. Accordingly hardness of compressor blades was lowered from 32-38 Rc to 20-26 Rc.

Other metallurgical and manufacturing advantages were gained by the reduction in hardness. They were:

1. Soft blades were found to be less susceptible to stress corrosion.

2. Impact strength was improved by the use of higher tempering temperatures.

3. Obvious heat-treating advantages derived from the relative ease of hitting the correct hardness range with the practically flat tempering curve in the range of 20-26 Rc.

4. Type 403 stainless iron is easier to cut in 26 Rc than in the 38 Rc condition.

5. A conservative estimate in-

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dicates that at least $50 per engine is saved when softer blades are used.

The authors conclude on a note of warning that at present there is inadequate service experience to draw strong, valid conclusions. Based on equivalent amounts of operational time in J-47 engines, however, incidence of blade failure for soft blades has been reduced in the order of 75-80%.

Harder Cermets by Electric-Resistance Sintering

Hardness and density of tungsten carbide-cobalt compacts can be increased by using an electric resistance sintering process in which heat and pressure are applied simultaneously to presintered compacts. Resistance sintering is primarily a method by which sufficient heat to induce plasticity is generated in a compact by the resistance offered by its constituent powder particles to the passage of an electric current of low voltage and high amperage. An important characteristic of the method is the rapidity with which a high degree of heat may be attained and the ease with which high pressure can be simultaneously applied upon the compact. P.G. Cotter, J.A. Kohn, and R.A. Potter of the Bureau of Mines report results of their work on compacts of this type in a report issued in January by the U.S. Dept. of the Interior. The authors describe the equipment, process and results of their work.

Materials and conditions

The materials used were standard-grade tungsten carbide and cobalt, as-received. A composition by weight of 94% tungsten carbide-6% cobalt was chosen since that composition is generally accepted as offering the optimum hardness consistent with

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*ease of cleaning

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acceptable toughness. The specimens were compressed at 12,000 psi and pre-sintered at 2200 F, though slightly different temperatures were used for other compositions.

The actual resistance sintering, which takes about 0.5 to 1.0 sec, is carried out in four steps: 1) welding heads close on the compact and exert pressure which is held throughout the cycle; 2) current is passed, which heats the compact to a controlled degree; 3) a hold period facilitates heat diffusion throughout the compact; and 4) current of higher density is applied, which heats the compact to the point at which the binding metal or contact points of the carbide grains soften, allowing the compact to be compressed to a higher density.

Results

Resulting compacts have superior hardness and slightly increased density. A change of the major binder phase from elemental cobalt to a ternary compound, probably Co_3W_3C, seems to be the primary reason for the increase in hardness.

The authors conclude that it should be possible to produce, by this method, compacts of diverse compositions for a variety of applications. For example, titanium carbide may be added to make a product suitable for metal shaping. Other potential additives are tantalum carbide, columbium carbide, chromium carbide and zirconium carbide. Production by this method is rapid and can be adapted to production-line procedures. However, there is a definite limit to the sizes, shapes and dimensional tolerances that can be held. Additional quality control is difficult to attain, unless close attention is paid to details of sizing, blending, and pressing of powders, maintenance of the electric-resistance equipment, and close supervision of the sintering process itself.

(Book Reviews on page 190)

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Books . . .

Symposium on Effect of Temperature on the Brittle Behavior of Metals with Particular Reference to Low Temperatures. *Published by American Society for Testing Materials, Philadelphia, Pa. Cloth, 474 pp. 6 by 9 in. Price $7.50.*

The symposium covered in this volume was developed by the Low Temperature Panel of the ASTM-ASME Joint Committee on the Effect of Temperature as a means of summarizing the existing knowledge on the subject.

Included are 27 papers with discussions on evaluation of brittle failures in ships and engineering structures, criteria of metal behavior for design engineers, metallurgical and mechanical factors, significance and reliability of notch toughness tests and some data on current research projects. The book is illustrated with graphs and photographs of brittle failures, and includes eighteen bibliographies appended to separate papers.

The book is a comprehensive survey of the field and will be useful to designers, engineers and metallurgists in practically all branches of engineering. It should be on the reference shelf of those engaged in the fabrication of chemical equipment for operation at low temperatures, large welded structures such as bridges, tanks and ships, and pipelines for the transmission of natural gas.

Report on the Elevated Temperature Properties of Selected Super Strength Alloys. *By Ward F. Simmons and Howard C. Cross. Published by the American Society for Testing Materials, Philadelphia, Pa. Paper, 208 pp. 8½ x 11 in. Price $4.75.*

This book is the third in the current series prepared under the auspices of the ASTM-ASME Joint Committee on the Effect of Temperature on Metals. It summarizes elevated - temperature strength data for 13 selected super-strength alloys. Included

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are 116 summary curves showing tensile strength, 0.2% offset yield strength, elongation and reduction of area, stresses for rupture in 100, 1000, 10,000 and 100,000 hr when available and stresses for creep rates of 1% in 10,000 and 100,000 hr. A brief description of each alloy including composition, recommended heat treatment and comments on forging and machining is included. The report also contains original data sheets from which the curves were derived.

This series of reports which is bringing up to date the Compilation published under the auspices of the Committee in the late 1930's is extremely valuable to anyone concerned with the application of metals at elevated temperatures. Engineers, designers and metallurgists in the field will find them indispensable.

Adhesion and Adhesives—Fundamentals and Practice. *Edited by F. Clark, John E. Rutzler and Robert Savage. Published by Society of Chemical Industry, London, England. Available in the United States from John Wiley & Sons, New York, N.Y. Cloth, 229 pp. 8¾ x 11¼ in. Price $9.75.*

This volume contains the papers read at two conferences held simultaneously in London and at the Case Institute of Technology on the use of high polymers in industry.

The first section dealing with fundamentals consists of 14 papers. Topics discussed include survey of adhesion and types of bonds, theory of adhesion, mechanism of adhesion, the energy of adhesion and the relation between friction and adhesion.

The second section dealing with practice consists of 29 papers on such topics as types and uses of adhesives for glass, paper, woodworking, metals and plastics. Included also are discussions of pressure sensitive tapes, recent developments in synthetic adhesives and testing.

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The volume contains contributions from 53 specialists and is a summary of the status of adhesion and adhesive bonding in the Spring of 1952 when the conference was held. It will, however, furnish an excellent background for additional work in the field.

41st Annual Proceedings American Electroplaters' Society. *New York, N.Y. Cloth, 8½ x 11½. 288 pp. Price $7.00 U.S. and Canada, $10.00 Foreign.*

This volume contains 45 papers which were presented at the 1954 convention. Included are papers on plating procedures, control of plating solutions, metallized non-conductors, control of wastes and finishing shop management problems. Reports of the discussion which followed presentation of the individual papers are included.

Safety in Industry: An Introduction to the Protection of Personnel. *By D. I. Macfarlane. Published by Iliffe & Sons Ltd., London, England, 1955. Paper 8¾ x 6 in. 71 pp. Price 7s. 6d. (postage extra).*

Safety in Industry is a general introduction to the subject and gives details of a number of means whereby plant and premises can be made safer and personal protective measures more effective. The special dangers of rotating machinery are well brought out. The control of dust and fumes, causes of much ill-health in the past, is dealt with, and types of modern protective clothing, boots and helmets surveyed. The prevention of skin diseases and protection of the eyes are considered, and there is a section on the precautions to be taken against harmful radiations arising from the industrial use of x-rays and radioactive substances. Finally, the important question of good lighting and flooring is discussed.

(More Book Reviews on page 196)

YOU FURNISH THE PRINT, WE'LL FURNISH THE PART

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OF SYNTHANE LAMINATED PLASTICS
RESISTS MOISTURE, HEAT, ARCING, BREAKAGE

Practically everything made requires a combination of several properties. And this terminal insulator is a shining example. It has to have high dielectric strength in a machinable insulator, good moisture resistance, excellent arc resistance, good heat resistance and mechanical strength. These and other requirements indicate *Synthane* laminated plastics for the job.

Starting with the blueprint, *Synthane* Corporation produces the needed base material with the right combination of properties, machines it with accuracy, and supplies the finished parts, with no waste, to the customer.

Each year *Synthane* turns out thousands of different finished parts. They are made from the more than 33 different grades of *Synthane* laminated plastics which are also regularly supplied to industry in sheets, rods, tubes, and molded parts. Good service and quality are characteristic of *Synthane* fabrication.

If you are looking for parts with many different properties — physical — mechanical — electrical — and chemical, in combination, *Synthane* may be your answer. Mail the coupon for information.

SYNTHANE CORPORATION, 3 River Road, Oaks, Pa.
Please send me more information about Synthane laminated plastics and fabrication service.

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SYNTHANE
LAMINATED S PLASTICS

SYNTHANE CORPORATION • OAKS, PENNSYLVANIA

For more information, turn to Reader Service Card, Circle No. 367

Contents Noted

Books . . .

Recommended Practices for Metallizing: Part IC-Application of Metallized Coatings to Protect Against Heat Corrosion. *Published by American Welding Society, New York, N. Y., 1954. Paper, 6 x 9, 9 pp. Price 50¢.*

Heat corrosion, a subject of much concern in the oil refinery, chemical plant, furnace industry and other high temperature fields, is the subject of the third report in the series under the general title, "Recommended Practices for Metallizing". This Standard provides an authoritative source of information dealing with the application of metallizing for providing protection against heat corrosion for temperatures up to and over 1800 F.

Equipment requirements and methods of surface preparation are listed in detail. The metallizing procedure, including wire and sealer composition, and inspection tests are also given as well as typical coatings for specific applications.

The Measurement of Particle Size in Very Fine Powders. *By H. E. Rose. Published by Chemical Publishing Co., New York, N.Y. Cloth, 5 x 8 in. 127 pp. Price $2.75.*

This book consists of four lectures discussing the methods of determining particle shape and size from the viewpoint of recent developments and research in progress.

In Lecture 1, size frequency, specific surface and particle shape are discussed together with examples citing the industrial importance of these quantities. Lecture 2 deals with size frequency determination, Stoke's law and apparatus for the determination of particle size by elutriation and sedimentation methods. Lecture 3 discusses photo-extinction methods of particle size determination while Lecture 4 covers methods of determining specific surface by gas absorption.

(More Book Reviews on page 198)

Lesson for today: How Fosbond locks paint to metal

Even when the heat's on, the Nesbitt ventilating and heating units in this modern Abington Township, Pa., school keep their smooth handsome finish. Thanks to the Fosbond® precoat, the paint resists the wear-and-tear of small-fry on the rampage . . . as well as the variations in temperature.

The secret is the way the Fosbond anchors the paint to the metal. After bonding itself firmly to the metal, the Fosbond coating presents a uniform surface of microscopic "teeth" which lock on the organic finish for lifetime adherence and protection.

Since John J. Nesbitt, Inc., adopted Fosbond, the company has not had one reject for paint adhesion. Cleaning and coating costs have been reduced.

If you use organic finishes on your product, you should know the full story of the Fosbond Process . . . and you should investigate the advantages of affixing the Fosbond-Good Housekeeping emblem to your products.

A free, one-hour survey of your finishing processes may make it possible for you to add more sales-appeal and lasting good looks to your products. Write: Customer Service Dept., Pennsalt Chemicals, 985 Widener Building, Philadelphia 7, Pa.

FOSBOND

Pennsalt Chemicals

Pennsylvania Salt Manufacturing Co.

For more information, turn to Reader Service Card, Circle No. 356

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Books . . .

Industrial Design in America, 1954. *Edited by the Society of Industrial Designers. Published by Farrar Straus and Young, New York 3, N.Y. Cloth, 8½ x 11 in. 224 pp. Price $12.50.*

Marking the 10th anniversary of the founding of the Society, this book presents a picture and text survey of the newest and best in the field.

The introduction by Arthur A. Houghton, Jr., President of Steuben Glass, Inc. is an essay on the place of design and the industrial designer in our modern industrial society. Prefacing the nine sections of the book are editorial reports by some of the nation's prominent business executives. These reports and sections deal with various aspects and developments in industrial design, appearance design, better use of materials, visual selling aids, new approaches, lowering the cost of manufacture, safety and health, color, product character, and convenience of use. Finally, there is an illustrated section devoted to foreign design.

Reports . . .

Dispersion Effects on Alloys Effect of Dispersions on Mechanical Properties. *John E. Dorn and C. Dean Starr, University of California, Institute of Engineering Research, Berkeley, Calif., Nov. 1953. PB 114678, 42 pp, graphs, tables. Available from Library of Congress, Publication Board Project, Wash. 25, D. C. Microfilm $2.75, Photocopy $6.50.* A brief summary of the dependence of properties on the microstructures of poly-phase alloys are presented.

Organic Finishes Fundamental Properties of Organic Finishes, Final Report under Contract N5-ori-111, Task order V. *B. G. Brand, E. R. Mueller, E. E. McSweeney, A. E. Austin, C. M. Schwartz, and H. R. Nelson, Battelle Memorial Institute, Columbus, Ohio, Apr. 1949. PB 111463, 10 pp. Available from Office of Technical Services, U. S. Dept.*

TUTHILL PUMP COMPANY EXPERIENCES...

"NO FAILURES

SINCE USING

STRESSPROOF®

SEVERELY COLD-WORKED, FURNACE-TREATED STEEL BARS

SAVES MONEY, TOO!"

Tuthill Model L Series mechanically sealed pumps are used in lubricating, hydraulic, transfer and burning oil service. Capacities range from 1/3 to 6 g.p.m. at pressures up to 600 p.s.i. The rotors for these dependable industrial pumps are made from La Salle STRESSPROOF.

●Tuthill knows the rotor is the heart of their pump. Quality cannot be compromised. For more than 10 years, Tuthill has used STRESSPROOF for rotors (replacing heat-treated alloy steel) without a failure!

Strength is required in these rotors to transmit the power through the shaft to the idler gear. Extremely high operating speeds mean the rotors must be straight. Wearability is an absolute necessity if the rotors are to stand up under severe operating conditions.

STRESSPROOF has all of these qualities. In addition, it is readily machinable. Its in-the-bar strength eliminates heat treating with its distortion, cleaning and subsequent machining problems. No rough machining, heat treating and finish machining with STRESSPROOF. The rotors are finish-machined from the bar.

STRESSPROOF's minimum warpage eliminates all straightening operations in this case. Its wearability keeps the rotor running year after year. It also provides real savings in both material and manufacturing costs.

STRESSPROOF makes a better part at a lower cost.

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helpful data bulletin No. 15... "Improve Quality— Cut Costs"

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MANUFACTURERS OF AMERICA'S MOST COMPLETE LINE OF QUALITY COLD-FINISHED STEEL BARS

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Contents Noted

Reports . . .

of Commerce, Wash. 25, D. C. $.50. Electron diffraction, electron microscopy, and X-ray diffraction were employed in this investigation. The objectives were to obtain information concerning the internal structure of organic finishes and the interfacial properties of both the finishes and the metal surfaces to which they are applied.

Nickel-Beryllium Report on Nickel-Beryllium Alloys. *F. M. Walters, U. S. Naval Research Laboratory, July 1940. PB 114796, 18 pp, graphs, tables. Available from Library of Congress, Publication Board Project, Wash. 25, D. C. Microfilm $2.00, Photocopy $2.75.* The tensile properties of six experimental nickel-beryllium alloys were determined for several heat treatments and the values found were equal to those appearing in the literature. Since nickel-beryllium alloys owe their strength to precipitation hardening, the limitations peculiar to such alloys are discussed.

Electrical Rubber Electrostatic Dissipation by Electrically Conductive Rubber. *Paul M. Rogers, U. S. Arsenal, Rock Island, Ill., Mar. 1954. PB 111414, 29 pp, photographs, tables. Available from Office of Technical Services, U. S. Dept. of Commerce, Wash. 25, D. C. $1.00.*

Stress-Strain Relations More Fundamental Approach to Plastic Stress-Strain Relations. *D. C. Drucker, Brown University, Graduate Division of Applied Mathematics, Providence, R. I., May 1951. PB 114805, 15 pp, drawings, diagrams, graphs. Available from Library of Congress, Publication Board Project, Wash. 25, D. C. Microfilm $2.00, Photocopy $2.75.* Essentially thermodynamic definitions of work-hardening and of ideally plastic materials are re-employed to remove an unnecessary assumption in the derivation of the general Mises-Prager plastic po-

For more information, turn to Reader Service Card, Circle No. 453

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Reports . . .

tential stress-strain relations. In particular it is shown that the loading surface or any of the customary yield curves for work-hardening or ideally plastic materials must be convex. The meaning of corners in such curves or vertices in the loading surfaces is discussed with special reference to problems of uniqueness.

Organic Fibers Manufacture of Superfine Organic Fibers. *V. A. Wente, E. L. Boone, and C. D. Fluharty, U. S. Naval Research Laboratory, May 1954. PB 111437, 18 pp, photographs, drawings, diagrams, graphs, tables. Available from Office of Technical Services, U. S. Dept. of Commerce, Wash. 25, D. C. $1.00.* An adjustable extruder forces a hot thermoplastic melt through a row of fine orifices into high-velocity dual streams of heated gas, usually air. The nozzle design provides for immediate resumption of attenuation following breaks. Nylon, linear polyester, polytrifluorochloroethylene, silicone, polystyrene, and other fibers can be produced. Materials such as polyvinyl chloride and polyacrylonitrile cannot be employed in this process. Proper balancing of all the variables yields fine fibers of good uniformity and quality.

Patents Ceramic, Paper, Rubber, Textile, Wood, and Other Products and Processes: Government-owned inventions available for license, U. S. Government Patents Board, 1954. *PB 111470, 30 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Wash. 25, D. C. $1.00.* Described in this book are 308 Government-owned inventions covered by patents active as of Dec. 31, 1953. For each invention, the title of the invention, the U. S. patent number, the name of the inventor, the name of the Government agency administering the patent, and an abstract of the patent are given.

(More Reports on page 204)

NO. 30 OF A SERIES

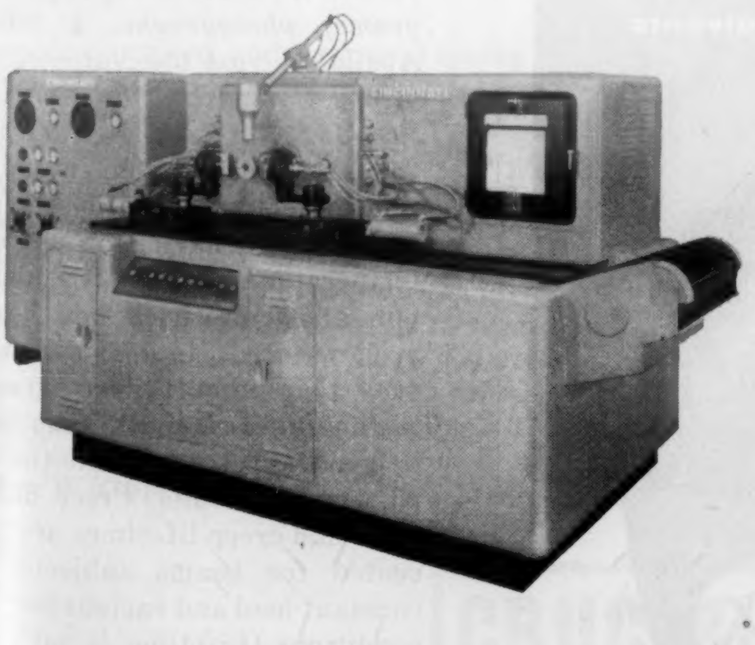
what's new?

e growing versatility of the standard lamatic hardening machine

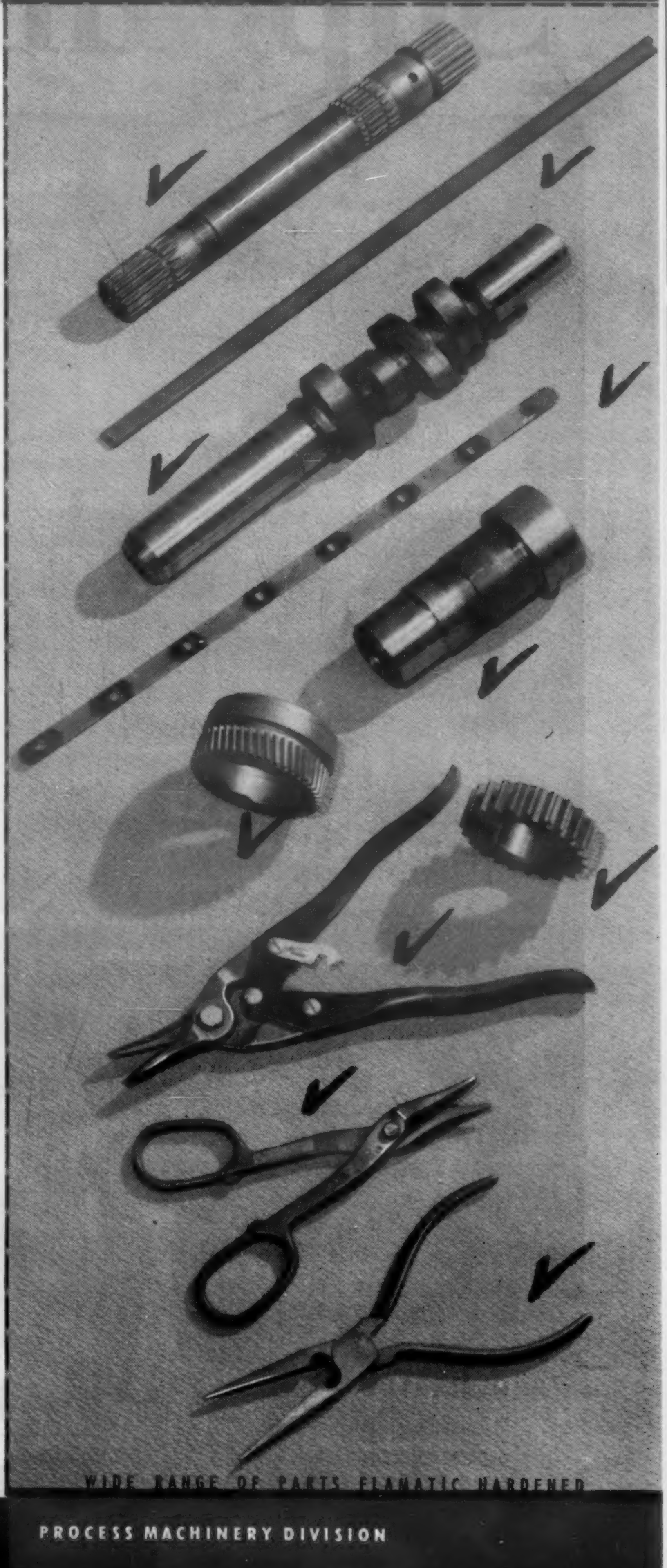
Put two automotive timing sprockets (part shown top right) on a standard Cincinnati Flamatic hardening machine, push the button, and in a few seconds they've automatically dropped into the conveyorized quench tank. Exclusive Flamatic electronic control holds temperature so close that the hardness pattern and value are uniformly maintained. Material: S.A.E. 1146 steel. Production rate: 200 parts per hour. Operations automatic except for loading. Rejects nil.

A surprisingly wide range of parts can be hardened in production on standard Flamatic machines with fairly simple tooling and easy changeover to new jobs. Maintenance is practically no problem, and you can use any fuel gas.

Write for the new Flamatic Catalog: Publication No. M-1861.




AUTOMOTIVE TIMING SPROCKET


WIDE RANGE OF PARTS FLAMATIC HARDENED

flamatic

PROCESS MACHINERY DIVISION

THE CINCINNATI MILLING MACHINE CO.
CINCINNATI 9, OHIO, U.S.A.

For More Information Circle No. 473

Contents Noted

Reports . . .

Aluminum Stress Corrosion Influence of Exposed Area on Stress-Corrosion Cracking of 24S Aluminum Alloy. *William H. Colner and Howard T. Francis, Armour Research Foundation, Nov. 1954. NACA TN 3292, 22 pp, diagrams, photographs, tables. Available from the National Advisory Committee for Aeronautics, 1512 "H" St., N.W., Wash. 25, D.C.* Results are presented of a study of the "area effect" in 24S aluminum alloy. This effect is the phenomenon whereby small exposed areas show long times to stress-corrosion failure, whereas large areas show short times. The effects of stress level, degree of sensitivity of the alloy, and hydrogen peroxide concentration in the corrosion medium were studied. Hydrogen peroxide decomposition and the substitution of oxygen for peroxide were also investigated.

Strength and Creep of Aluminum Investigation of Static Strength and Creep Behavior of an Aluminum-Alloy Multiweb Box Beam at Elevated Temperatures. *Eldon E. Mathauser, Nov. 1954. NACA TN 3310, 21 pp, diagrams, photographs, 4 tables. Available from the National Advisory Committee for Aeronautics, 1512 "H" St., N.W., Wash. 25, D.C.* Results of an investigation to determine static strength and creep behavior at elevated temperatures of 24S-T3 aluminum-alloy multiweb box beams are presented. Methods that were used to predict failure stresses in the static-strength tests were in good agreement with the experimental results. Creep deflections and creep lifetimes are presented for beams subjected to constant load and various heating conditions. Lifetime is satisfactorily predicted from material stress-rupture data when tensile failure occurs at both constant and varying temperatures.

news of ENGINEERS

gineer, of the recently reorganized Engineering Dept., Mark Simpson Manufacturing Co.

R. J. Studders, magnet development engineer, Carboloy Dept., General Electric Co., has been appointed manager of magnetic products engineering for the company to succeed **E. E. George,** recently appointed plant manager of Carboloy Dept.'s permanent magnet plant.

Herbert B. Clark has been made executive vice president, Fansteel Metallurgical Corp., and its subsidiaries, Vascoloy-Ramet Corp., WW Alloys, Inc., and Tantalum Defense Corp.

Edward B. Bitzer has been made assistant manager of the Nickel Alloys Dept., the International Nickel Co., Inc. Other appointments in the company include **Albert P. Gagnebin** as assistant manager of the Nickel Sales Dept. and **Keith D. Millis** to succeed Mr. Gagnebin as head of the Ductile Iron Section, Development and Research Div.

Dr. Ernest S. Hedges has been appointed director, International Tin Research Council, and director, Tin Research Institute, to succeed **John Ireland,** who has retired. **Dr. W. E. Hoare** and **W. R. Lewis** have been made assistant directors.

Earl F. Riopelle has been promoted to vice president in charge of research and engineering, Houdaille-Hershey Corp.

M. W. Reynolds has been made general manager, Acheson Colloids Co., and **P. C. Buck** has been named to take charge of engineering and production for Acheson Industries, Inc. Both are vice presidents of Acheson Industries, Inc.

E. A. Tice, formerly a member of the Corrosion Engineering Section, Development and Research Div., the International Nickel Co., Inc., has been transferred to the Div.'s New England Technical Field Section.

(More News on page 210)

that's the ticket!

When the job calls for a low cost **hardenable stainless steel...**

17-4-PH

gets the nod. It is especially resistant to sea water corrosion and pitting and is recommended for ship propellers, pump impellers, marine applications, and a variety of uses involving the handling of foods and chemicals where corrosive conditions are mild. 17-4-PH is a precipitation hardenable alloy, quality cast at Cooper Alloy to the following typical composition:

Carbon **.04** / Chromium **16.50** / Nickel **3.40** / Copper **3.65**

Typical Mechanical Properties (Age Hardened)

T.S. (psi)	**179,000**	Red. Area %	**7**	Brinell	**388**
Y.S. (psi)	**150,000**	% Elong. 2"	**4**		

Complete data on request.

COOPER ALLOY
CORPORATION • HILLSIDE, N. J.

• *Foundry Products Division*

COOPER ALLOY

CORPORATION BRIEFS

• Edited by GEORGE BLACK

IT COULDN'T BE CAST... BUT IT WAS

You'll be hearing a lot of talk about the jet engine support which foundries had tried to cast in green sand, dry sand, core mold and lost wax. They said it couldn't be cast . . . but they didn't count on that COOPER ALLOY *advanced know-how* which has made the difference in so many cases. It's now a regular production item in our Foundry Products Division . . . in spite of the fact that each piece is custom cast. Shell molding plus experience and the will to tackle the tough ones, did the trick. If you haven't reserved your set of Advanced Know-How case histories which are soon to be published—there's still time. A note on your company letterhead is all you need.

VALVES IN PAPER AND PULP

Chief Engineer of Cooper Alloy's Valve and Fitting Division, Perc Shaffer, recently delivered one of the most comprehensive lectures on the subject of stainless steel valves in the pulp and paper industry. It was printed in toto in the Pulp and Paper Magazine of Canada, and is now available in reprint form from our technical librarian.

VANTON PUMP MOVES

Vanton Pump & Equipment Corp. has announced the removal of its executive and sales offices from the Empire State Building in New York to the plant location at Sweetland Avenue, Hillside, N.J. The move is the result of increased design and production activity which demands closer liason between operating and management levels. We anticipate faster action on design changes to increase the versatility and usefulness of this unique pump without a stuffing box. The first such change, involving the shift of bearings to the exterior of the housing, has just been completed. Details on request!

COOPER ALLOY
CORPORATION • HILLSIDE, N. J.

C.B.4

For more information, turn to Reader Service Card, Circle No. 452

news of | ENGINEERS

E. V. Dowden, manager of Osborn Manufacturing Co.'s Brush Div., has ben named a vice president of the company.

John A. Clements has been made supervisor of manufacturing methods and time standards in the Carboloy Dept., General Electric Co.

J. S. Parker has been made general manager, Aircraft Gas Turbine Div., General Electric Co.

T. W. Kuhn has been elected executive vice president, and **C. M. Adams,** vice president, Bohn Aluminum & Brass Corp.

Sidley O. Evans has been appointed to the newly created position of manager of tubing operation, Tubular Products Div., the Babcock & Wilcox Co. **David A. Edgecomb** has been named to succeed Mr. Evans as superintendent of the Extrusion Dept.

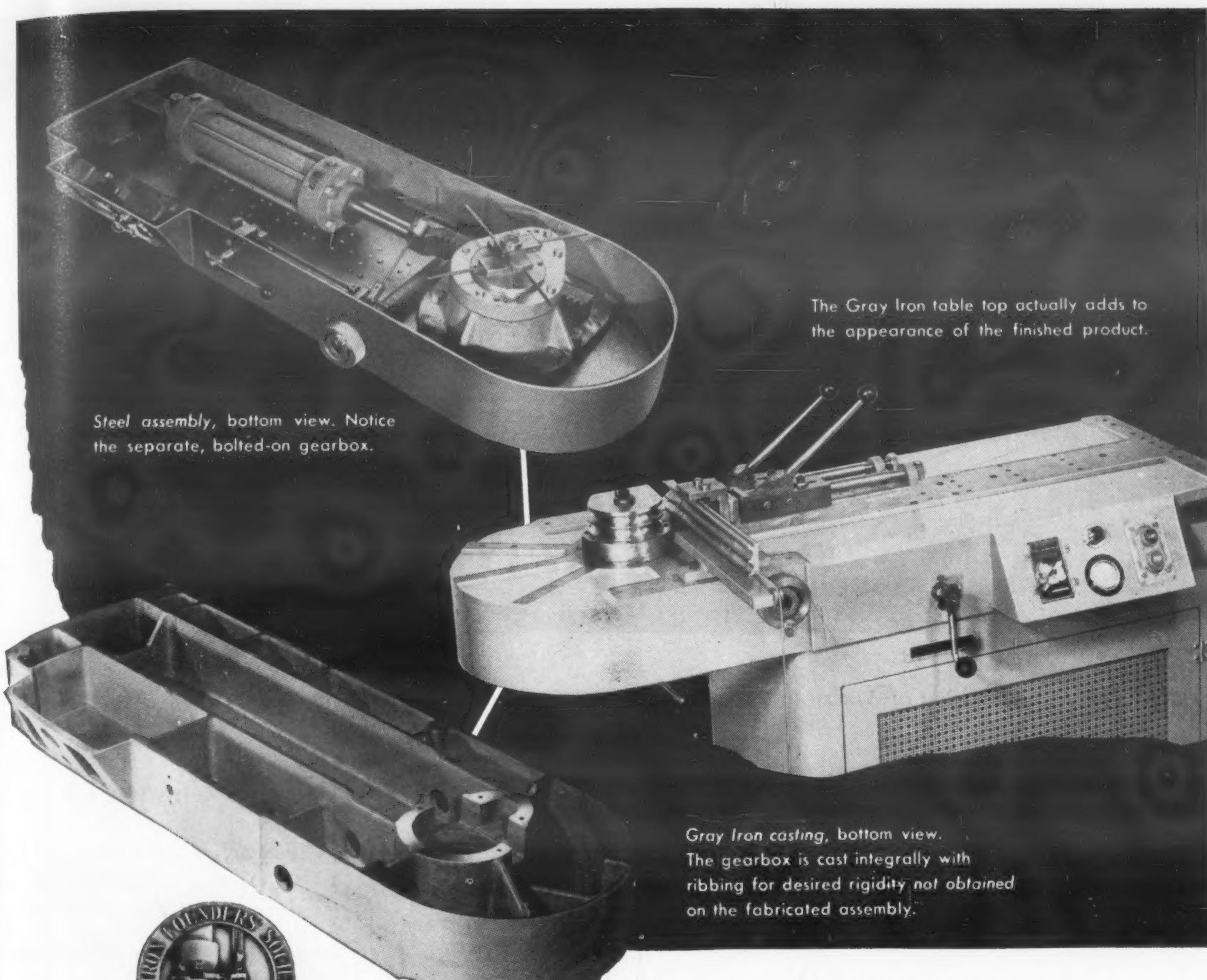
Dr. William H. Schuette, formerly manager, Plastics Production Dept., the Dow Chemical Co., has been promoted to assistant to the general manager in the Midland Div. of the company. **Max Key** succeeded Dr. Schuette as manager of the Plastics Production Dept.

Dr. Theodore I. Leston has been appointed executive vice president, Permagile Corp. of America, a new affiliate of the American Agile Corp., and **William B. Kriewall,** vice president in charge of research, development and production.

Dr. Kurt C. Frisch has been appointed assistant manager of research, E. F. Houghton & Co., and has been succeeded by **Dr. Ellis Abrams** as supervisor of organic research for the company.

W. Harvey Thompson and **H. A. Chandor, Jr.** have been named vice presidents of the Riverside Metal Co. Div., H. K. Porter Co., Inc.

Harry Cotesworth has been named chief engineer, Development Dept., the Cleveland Crane



This symbol assures you the most for your casting dollar

Here's why it pays to call in one of the more than 500 leading foundries displaying the Society symbol:

- The most recent technical and business information is available to each member through the Society to help you design better products at lower cost.
- The use of sound cost accounting procedures is recommended and encouraged among Society member foundries, assuring full value for your casting dollar.
- Improved castings result from the advanced techniques and the high sense of responsibility of Society members.

MAKE IT BETTER WITH GRAY IRON

15 Hours Saved ...by Casting in Gray Iron

Producing these machine table tops in Gray Iron takes 7½ hours. Previously, the tops were fabricated of torch-cut steel segments, requiring 22¾ hours.

Redesigning in Gray Iron has increased the rigidity of the table tops, improved their appearance and simplified production operations.

There are many valuable advantages which Gray Iron castings can offer *you.* Call your nearest Society member foundry and through him the full facilities of this association are available to help you.

Or, write direct to Gray Iron Founders' Society, Inc., National City-E. 6th Bldg., Cleveland 14, Ohio, for helpful technical and business information.

GRAY IRON FOUNDERS' SOCIETY

For more information, turn to Reader Service Card, Circle No. 317

& Engineering Co., and **Kurt R. Weise,** chief engineer, Cleveland Tramrail Div. of the company.

D. T. O'Connor has been appointed director of industrial x-ray engineering, Machlett Laboratories, Inc.

Robert M. Wilson, Jr. has been appointed development engineer in the power field, Development and Research Div., the International Nickel Co., Inc.

A. H. Schmal has been made manager of the Products Development Laboratory, Borg-Warner Corp.

Dr. John T. Rucker, Jr. has been appointed administrative assistant to the director of research and development, Hooker Electrochemical Co.

Joseph Keith Balkwill has been made senior research assistant in the Engineering Research Group of Electro Metallurgical Co.'s Metals Research Laboratories.

John J. Murray and **Richard Doughton, Jr.** have been appointed development engineers in the Product Development Div., Jones & Laughlin Steel Corp.

John D. Russell, formerly manager of engineering, Joy Manufacturing Co., has been appointed vice president, engineering, of the company.

Joseph C. Fox has announced the opening of an office at 4401 Jackman Road, Toledo 12, Ohio, for consultation on matters pertaining to chemical and metallurgical phases of the die casting process.

K. O. William Sandberg has been appointed manager of engineering, and **Arthur T. Bourgault** manager of the custom molding plant, in the Plastics Dept., General Electric Co.

Joseph Hyman has been elected vice president and technical director, Catalin Corp. of America.

Joseph C. Buechel has been appointed manager of a new design

ASTONISHING . . . a plastic film with impact strength like this

CHALLENGING to industry . . . the combination of remarkable properties offered by Du Pont MYLAR*

Here's a plastic film that can "take it"! But the exceptional strength of new Du Pont "Mylar" polyester film is only one of the remarkable properties that you can use to improve a product.

• Is space reduction important to your product? The thinness of tough Du Pont "Mylar" may permit you to design smaller equipment.

• Does your product operate at extremes of temperature? "Mylar" retains its operating efficiency from -80°F. to 302°F.

• Need more efficient insulation? "Mylar" has exceptional dielectric strength.

• This versatile film can also be slit into yarn; it can be metalized; it can be bonded to other materials to make durable protective and decorative laminates.

It will pay you to find out more about the properties of "Mylar," and the amazing variety of fields in which "Mylar" is improving products, cutting costs. Mail the coupon for your copy of a new booklet that gives you the facts and figures. It may well suggest ways for you to profit from this new resource of industry. Write: E. I. du Pont de Nemours & Co. (Inc.), Film Department, Wilmington 98, Delaware.

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**Du Pont registered trade-mark for its brand of Polyester Film.*

For more information, turn to Reader Service Card, Circle No. 397

news of ENGINEERS

and development section of the Small Aircraft Engine Dept., General Electric Co.

George W. Jernstedt has been appointed director of a new manufacturing laboratory, Westinghouse Electric Corp.

news of COMPANIES

National Standard Co. has purchased **Kenmore Metals Corp.,** 380 Ninth St., Jersey City, N. J.

Kropp Forge Co. recently completed a $6,000,000 improvement and expansion program, providing new facilities for all phases of forging operation.

The **American Brass Co.,** wholly owned subsidiary of Anaconda Copper Mining Co., recently announced plans for construction of an integrated aluminum mill at Terre Haute, Ind.

North American Philips Co., Inc., has announced that the twentieth session of the Norelco X-ray Diffraction School for research and industrial registrants will be held at its plant the week of April 4-8.

Kaiser Aluminum & Chemical Corp.'s Chemicals Div. has announced plans to build a $4,000,000 plant to produce basic refractories at Columbiana, Ohio.

Hess, Goldsmith & Co. has acquired full ownership of **Glass Fabrics Finishing Corp.**

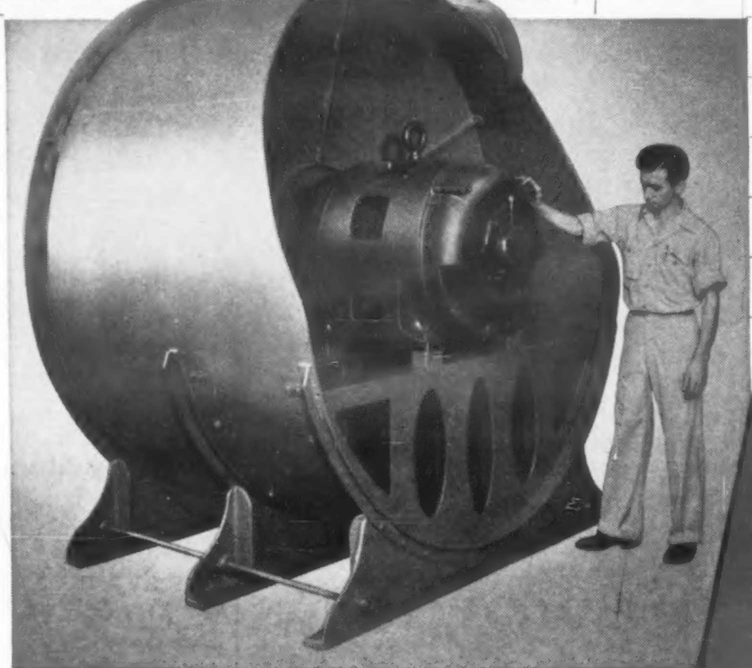
The **Duriron Co., Inc.,** has purchased the assets of the **Enzinger Union Corp.,** Angola, N. Y. The plant at Angola will operate as the Enzinger Div. of the Duriron Co.

Furane Plastics has announced the expansion of its activities in the field of epoxy tooling resins by taking over certain epoxy formulating activities of Wal-Mar Plastics, Inc.

The **Mercast Corp.** has purchased the entire stock interest held by **National Bronze & Aluminum**

Repeat Orders Tell the Story

	Jan. 1, 1940		Jan. 1, 1954	
	No. of Units	Total H.P.	No. of Units	Total H.P.
ALUMINUM CO. OF AMERICA	71	407	397	1962
AMERICAN CAN CO.	64	287	[illegible]	755
CHRYSLER CORP.	10	[illegible]	204	2245
FORD MOTOR CO.	59	1152	253	4020
SUNSHINE BISCUIT CO.	19	76	78	652
WESTINGHOUSE ELECTRIC CORP.	65	377	206	3002
AMERICAN BRASS CO.	32	120	117	616
ALLEGHENY-LUDLUM STEEL CORP.	42	393	87	978
GOODYEAR TIRE &	29	75	66	159
			655	14421
			379	3261
			174	1324
			227	888
			260	2574
			154	761



SPENCER HARTFORD TURBOS

THE RECOGNIZED STANDARD FOR MORE THAN 30 YEARS

Spencer Turbos have been recommended by more than thirty oven and furnace manufacturers for more than a quarter of a century. In addition hundreds of large manufacturing companies have standardized on Spencer and placed repeat orders from year to year. (See above).

Simplicity, reliability and long life are the reason for this universal acceptance. If you wish to study the outstanding advantages of the Spencer Turbo and its many applications, ask for General Bulletin No. 126-A and the Turbo Data Book No. 107-D.

THE SPENCER TURBINE COMPANY

SPENCER HARTFORD

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494-J

Manufacturers of Turbo-Compressors and Heavy Duty Vacuum Cleaners

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news of COMPANIES

Foundry Co. in one of its licensees, **Alloy Precision Castings Co.,** of Cleveland.

Hooker Electrochemical Co. and **Durez Plastics & Chemicals, Inc.,** have negotiated for a merger of Durez into Hooker. The Durez company is expected to operate as a division of Hooker Electrochemical Co. and will retain its name.

Pennsylvania Salt Manufacturing Co. has acquired the assets of the **Gilron Products Co.** and its organization is being integrated with the parent company's Metal Processing Department.

South Chester Tube Co. has purchased **Dodge Steel Co.,** Philadelphia.

The **Baldwin-Lima-Hamilton Corp.** has purchased the **Erwin Loewy Hydropress** interests as part of its diversification program.

Harvey Aluminum will claim title to the West's largest aluminum building on completion of its heavy press facility in Torrance, Calif.

Bendix Aviation Corp. has changed the name of its Eclipse-Pioneer Foundries Div. to Bendix Foundries.

The **Carborundum Co.** has established a new operating unit, the Electro Minerals Div., to manufacture and sell silicon carbide and fused alumina crudes, abrasive grain and related electric furnace products in the United States. Facilities included in the new division are at Niagara Falls, N. Y., and Vancouver, Wash.

Koppers Co., Inc., has expanded the operations of its Metal Products Div. in Baltimore, Md., by purchase of the **F. X. Hooper Co., Inc.,** to operate as a subsidiary. Koppers has also announced plans to spend in excess of $20,000,000 during 1955 for new plants and equipment and in enlarging and improving present production facilities. Of this amount, sizeable

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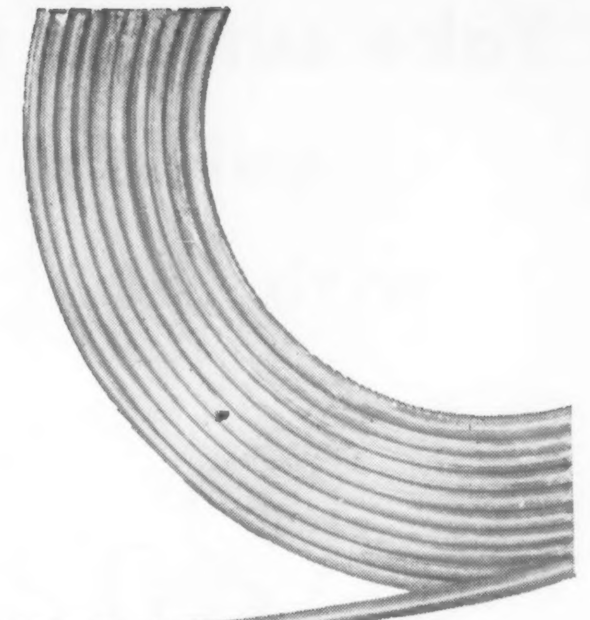
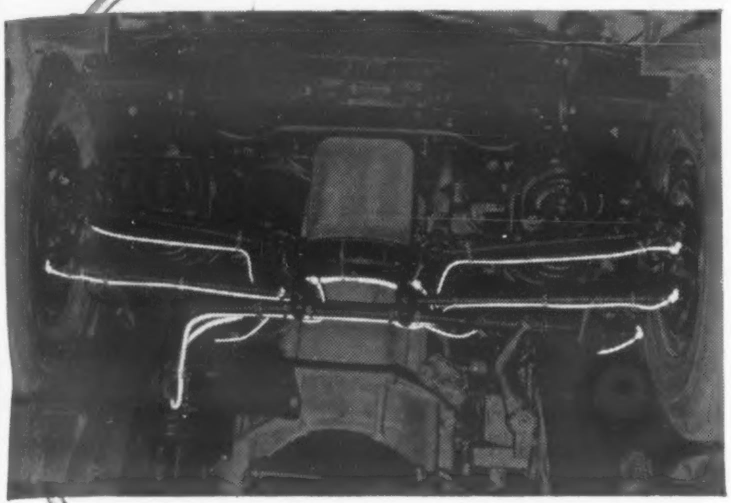
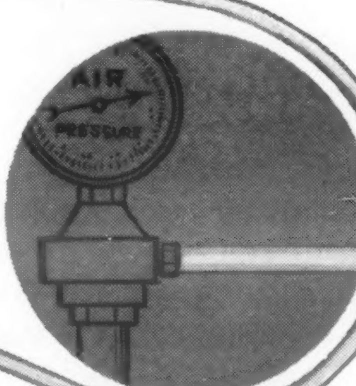


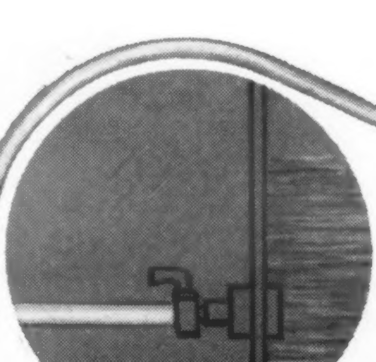


Just think of the many uses for a tubing with all of nylon's abrasion and corrosion resistance, flexibility, resiliency, and other desirable properties! What's more, NYLAFLOW* tubing usually cuts initial tubing and assembly costs. There's no pre-bending, only two connections are needed, and you can use either standard flare or compression fittings. NYLAFLOW tubing is supplied in stock diameters and lengths, and in two grades: Type T with a tested bursting strength of 1,000 psi and Type H, 2,500 psi. Just take a look at some of its exciting possibilities!

NYLAFLOW* LUBRICANT LINES

In the new push-button power lubrication system for 1955 Lincoln and Mercury automobiles, Lincoln Engineering Co. of St. Louis chose NYLAFLOW tubing because it is dent proof and flexes as chassis members move. NYLAFLOW also costs less than other tubing tested, and is faster, cheaper, and easier to assemble and install.

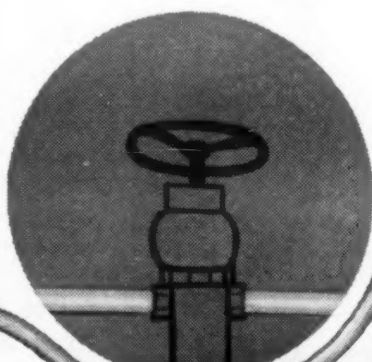




NYLAFLOW* AIR LINES

NYLAFLOW should give excellent results in air lines for pneumatic instruments and control valves, pneumatic equipment and tools, pumps and water systems, etc.

SEND FOR NEW NYLAFLOW TUBING BULLETIN



NYLAFLOW* FUEL AND OIL LINES

NYLAFLOW tubing's properties indicate added abrasion and fatigue resistance, as well as lower cost, for fuel and oil lines on internal combustion engines, etc.

NYLAFLOW* PROCESS LINES

NYLAFLOW is not subject to corrosion, nor is it attacked by most organic solvents, process gases or strong alkalies. This suggests it should be ideal for plant gas and fluid lines.

p

THE POLYMER CORPORATION of Penna. • Reading, Penna.

POLYMER *NYLAFLOW TUBING**

...nylon...Teflon...and other non-metallic shapes

In CANADA: Polypenco, Inc., 2052 St. Catherine W., Montreal, P.Q.

Teflon is the trademark for DuPont tetrafluoroethylene resin

*NYLAFLOW is the trademark for The Polymer Corporation's nylon tubing

For more information, turn to Reader Service Card, Circle No. 465

news of | COMPANIES

portions will go into the completion of a large plant at Port Arthur, Tex., to make polyethylene.

The **Babcock & Wilcox Co.** has purchased **Globe Steel Tubes Co.** of Milwaukee. The Globe company will be operated as a part of the company's Tubular Products Div.

Aluminum Co. of America has announced plans for a major addition to its aluminum rolling equipment, costing more than $5,000,000, at its Davenport works.

Detroit Sintered Metals Corp. has offered a new service to design engineers and production men. Bars of powdered metal 1½ in. in diameter by 2½ in. long will be supplied in any quantity for experimental purposes on new parts or redesigned old parts.

Standard Oil Development Co. has changed its name to Esso Research and Engineering Co.

news of | SOCIETIES

The **Society of Automotive Engineers** recently inaugurated Carl George Arthur Rosen, Consulting Engineers, Caterpillar Tractor Co., as its 1955 president.

The **Resistance Welder Manufacturers' Association** at their annual meeting elected J. C. Wilson, Jr., president, Acro Welder Manufacturing Co., as president for the coming year. David V. Uihlein, Banner Manufacturing Co., was elected vice president, and J. F. Deffenbaugh, Federal Machine and Welder Co., new chairman of the RWMA Technical Committee.

The **Institute of the Aeronautical Sciences** has elected Robert E. Gross, who is president and board chairman, Lockheed Aircraft Corp., as president for 1955. He succeeds J. L. Atwood, president, North American Aviation, Inc. Four vice presidents also elected include Roger Wolfe Kahn, test pilot and service manager, Grumman Aircraft Engi-

neering Corp.; T. Claude Ryan, president, Ryan Aeronautical Co.; Dr. Edward R. Sharp, director of Lewis Flight Propulsion Laboratory, National Advisory Committee for Aeronautics, and Edward C. Wells, vice president-engineering, Boeing Airplane Co.

The **American Institute of Mining and Metallurgical Engineers, Inc.,** has presented the first Benjamin F. Fairless Award to Stewart Joseph Cort, vice president, Steel Div., Bethlehem Steel Co., and director of the company, for his intense interest in the technology and development of the iron and steel industry.

The **National Metal Trades Association** has appointed Walter G. Koch, president, International Steel Co., to serve as chairman of the sixth annual Achievement Award Committee. Other members of the committee are John S. Higgins, president, Whittet-Higgins Co.; G. M. Stickell, vice president and general manager, Landis Machine Co.; Merle Harrod, president, the Wapakoneta Machine Co., and Harry D. Marshall, vice president, Gallmeyer & Livingston Co.

The **American Foundrymen's Society** has nominated Bruce L. Simpson, president, National Engineering Co., to head the society for the coming year. Frank W. Shipley, foundry manager, Caterpillar Tractor Co., has been nominated for vice president. In addition, six new national directors nominated include Curtis C. Drake, plant superintendent, Griffin Wheel Co.; C. W. Gilchrist, foundry superintendent, Cooper-Bessemer Corp.; O. J. Myers, technical director, Foundry Products Div., Archer-Daniels-Midland Co.; Charles E. Nelson, technical director, Magnesium Div., Dow Chemical Co.; Richard A. Oster, director, Beloit Vocation and Adult School, and Robert W. Trimble, foundry superintendent, Bethlehem Supply Co. New officers and directors will be elected during the AFS Foundry Congress in May.

(More News on page 222)

news of SOCIETIES

The **American Society of Mechanical Engineers** has appointed three new directors on the Council for the coming year. They are E. O. Bergman, staff-consultant, C. F. Braun & Co.; Jess H. Davis, president, Stevens Institute of Technology, and Joseph Pope, vice president and director, Stone & Webster Engineering Corp.

The **Aluminum Association** has elected Everett G. Fahlman, the Permold Co., as president to succeed D. A. Rhoades, Kaiser Aluminum & Chemical Corp., who has served as the Association's president for the past two years. Arthur V. Davis, Aluminum Co. of America, was re-elected chairman of the board; Donald M. White was re-appointed secretary and treasurer; and W. A. Singer, Apex Smelting Co., was re-elected director at large. Other new appointments include S. D. Den Uyl, Bohn Aluminum & Brass Corp., and D. A. Rhoades, directors at large; and the following vice presidents: L. M. Brile, Fairmont Aluminum Co.; Frank B. Cuff, Aluminum Co. of America; George N. Wright, Harsch Bronze & Aluminum Foundry.

The **American Rocket Society** has elected Vincent J. Cushing, assistant manager, Propulsion and Structural Research Dept., Armour Research Foundation of Illinois Institute of Technology, as president of the society's Chicago section for 1955. A. D. Kafadar, Manager of thermodynamics and heat transfer, Mechanics Research Dept., American Machine & Foundry Co., was elected vice president.

The **American Society of Mechanical Engineers** has named James D. Cunningham, president of Republic Flow Meters Co., and Alex D. Bailey, retired Commonwealth Edison Co. vice president, as co-chairmen of the 75th anniversary annual national meeting of the society to be held November 13-18 in Chicago.

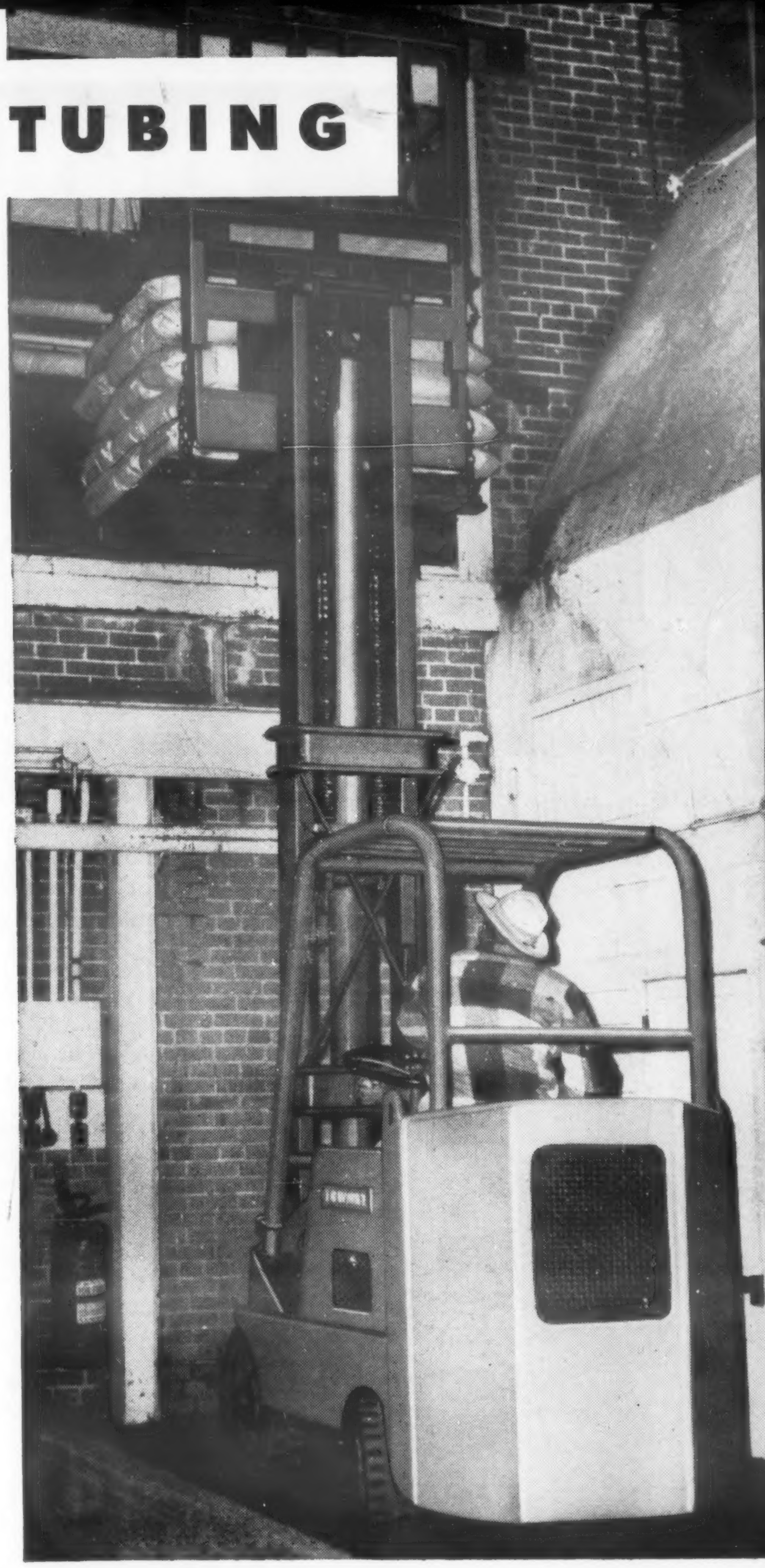
(*Meetings & Expositions* on p. 224)

HELBY SEAMLESS TUBING

puts the

LIFT

IN LIFT TRUCKS



The Towmotor is one of the most rugged top-perform- lift trucks in the country. And the lift mechanism of Towmotor features a standard mast which provides highest free lift—25½"—in the industry. The model wn here has a 6000 lb. capacity at 24" load center. y to this powerful, fast-hoisting action is the hydraulic st cylinder—the assembly that puts the "lift" into y load hoisted by the Towmotor. That hoist cylinder bricated from Shelby Seamless Mechanical Tubing. hock-absorbent Shelby Seamless Tubing combines to highest degree the desirable qualities of strength, ty and workability. It is uniform throughout, dimen- ally accurate, and possesses excellent machining and erior welding properties.

helby Seamless is produced to exacting standards by world's largest manufacturer of tubular steel prod- s. It is available in a wide range of diameters, wall knessess, various shapes and steel analyses. Please free to call on our engineers at any time. They will be d to submit recommendations based on a study of r particular requirements.

All Shelby Seamless Tubing is pierced from solid billets of uniform steel. This is the one manufacturing method that assures absolute uniform wall strength.

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SHELBY SEAMLESS MECHANICAL TUBING

4-1050

UNITED STATES STEEL

Meetings and Expositions

PRESSED METAL INSTITUTE, spring technical meeting. Cleveland. Mar. 16-18, 1955.

AMERICAN SOCIETY FOR METALS, Western Metal Congress and Exposition. Los Angeles. Mar. 28-Apr. 1, 1955.

SOCIETY OF THE PLASTICS INDUSTRY, INC., Pacific Coast Section conference. Palm Springs, Calif. Apr. 13-15, 1955.

SOCIETY OF AUTOMOTIVE ENGINEERS, aeronautic meeting, aeronautic production forum and aircraft engineering display. New York. Apr. 18-21, 1955.

SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS, spring meeting. Los Angeles. Apr. 27-29, 1955.

ELECTROCHEMICAL SOCIETY, INC., spring meeting. Cincinnati. May 2-5, 1955.

SOCIETY OF THE PLASTICS INDUSTRY, INC., annual meeting. Queen of Bermuda. May 7-15, 1955.

METAL POWDER ASSOCIATION, annual meeting. Philadelphia. May 10-12, 1955.

SOCIETY FOR APPLIED SPECTROSCOPY, annual meeting. New York. May 12-13, 1955.

INDUSTRIAL HEATING EQUIPMENT ASSN., INC., spring meeting. Hot Springs, Va. May 15-18, 1955.

PORCELAIN ENAMEL INSTITUTE, mid-year division conference. Chicago. May 18-20, 1955.

AMERICAN FOUNDRYMEN'S SOCIETY, annual convention. Houston. May 23-27, 1955.

AMERICAN SOCIETY FOR QUALITY CONTROL, annual convention. New York. May 23-25, 1955.

AMERICAN WELDING SOCIETY, Welding Show and Spring Meeting. Kansas City, Mo. June 7-10, 1955.

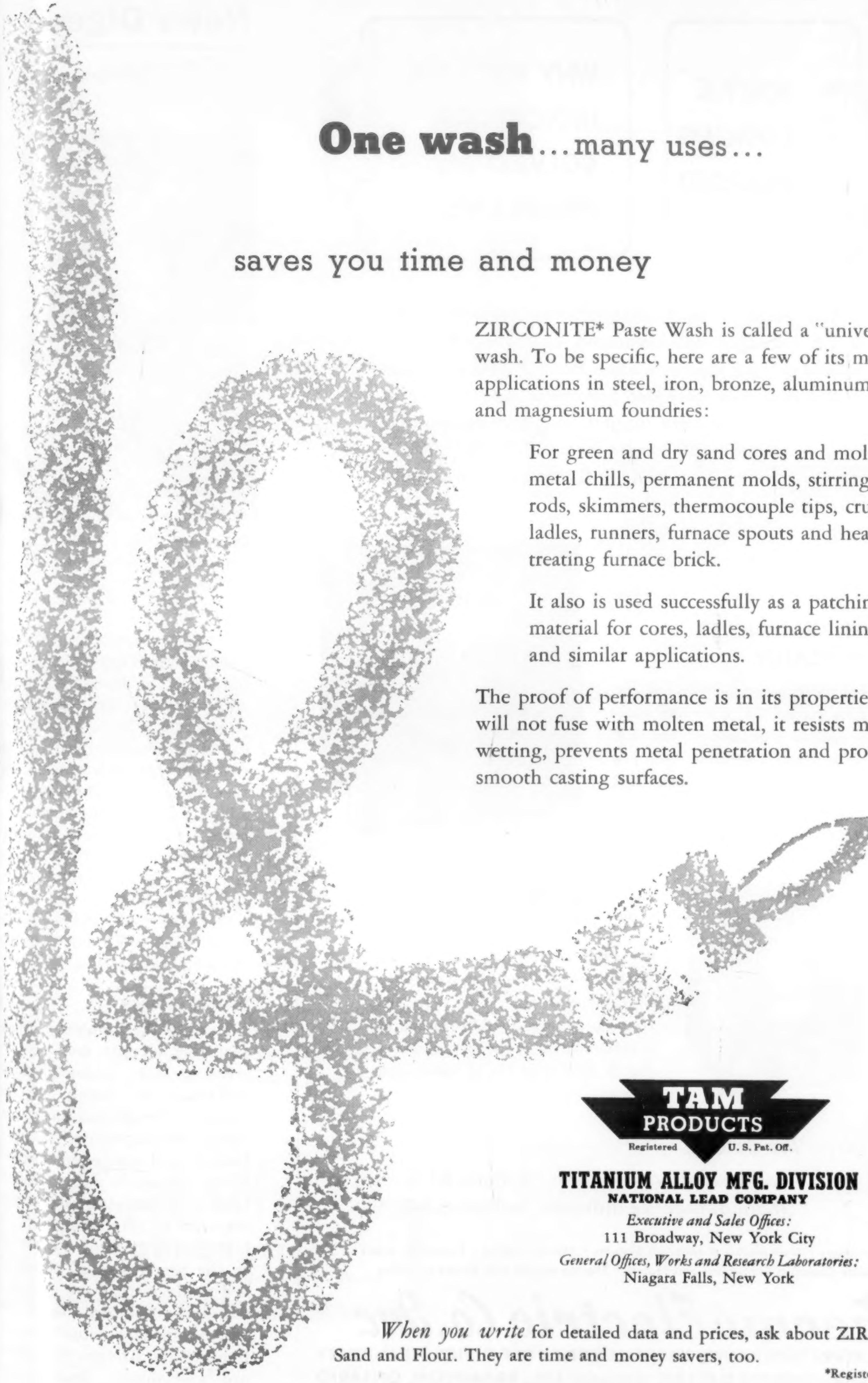
SOCIETY OF AUTOMOTIVE ENGINEERS, summer meeting. Atlantic City. June 12-17, 1955.

MALLEABLE FOUNDERS' SOCIETY, annual meeting. White Sulphur Springs, W. Va. June 16-18, 1955.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, semiannual meeting. Boston. June 19-23, 1955.

AMERICAN ELECTROPLATERS' SOCIETY, Industrial Finishing Exposition. Cleveland. June 20-23, 1955.

AMERICAN SOCIETY FOR TESTING MATERIALS, annual meeting. Atlantic City. June 26-July 1, 1955.



One wash...many uses...

saves you time and money

ZIRCONITE* Paste Wash is called a "universal" wash. To be specific, here are a few of its many applications in steel, iron, bronze, aluminum and magnesium foundries:

For green and dry sand cores and molds, metal chills, permanent molds, stirring rods, skimmers, thermocouple tips, crucibles, ladles, runners, furnace spouts and heat treating furnace brick.

It also is used successfully as a patching material for cores, ladles, furnace linings, and similar applications.

The proof of performance is in its properties. It will not fuse with molten metal, it resists metal wetting, prevents metal penetration and produces smooth casting surfaces.

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When you write for detailed data and prices, ask about ZIRCONITE* Sand and Flour. They are time and money savers, too.

*Registered trademark

For more information, turn to Reader Service Card, Circle No. 433

News Digest

continued from p. 1

***Close-up** of printed circuit plate connected to base containing printed wiring.*

has been accepted as the generic name of the many different techniques of printing, etching or embossing wiring. In its most widely used form, it should be called printed wiring, since circuit elements such as capacitors, resistors, and inductors are added to the printed circuit by more or less conventional soldering techniques. Strictly, printed circuitry is applicable only to such techniques as the ceramic wafer-silver ink process used to print capacitor and resistance elements in addition to wiring.

Still in infancy

Despite the number of manufacturers already using printed circuits, it is evident that the technique is barely off the ground. Design has outrun materials developments, standardization, and component compatibility. There is worry that the labor and materials cost savings inherent in printed circuits will lead in the heat of competition to the production of sub-standard products that are difficult if not impossible to repair, and which will have actually less reliability and lifetime than standard assemblies. Tooling costs

News Digest

continued

for etched circuits are low, if not almost non-existent by conventional standards, and it is easy to bond a copper foil to a phenolic base well enough to get through dip soldering. But it is difficult to get a satisfactory bond that will retain its strength with heat and aging, and will hold tightly in the face of vibration, humidity, and heat cycling.

Engineers concerned with the development and application of printed circuits are not satisfied with a mere printed equivalent to conventional circuitry. They weigh three factors almost equally: 1) elimination of conventional wiring; 2) adaptability to completely automatic assembly; and 3) minimization of size and weight. Any system that does not meet all of these factors is eyed askance. To attain automatic assembly in the most efficient manner, all components will have to be standardized to fit into some sort of modular system. At the present state of development, no one system of printed circuitry is superior to any other to the extent that it will be accepted as the basic standard for the industry.

The status of the various techniques and their limitations stack up as follows:

Etched wiring—The most widely used system at present, etched networks are made by printing an etch resist material on copper foil bonded to the insulating board. The board is dipped into an etchant and excess copper foil removed, leaving the printed circuit. The main advantage of the system is the absence of tooling, since the resist material can be applied by photographic or offset techniques. Disadvantages include degradation of the insulator by the etchant, and degradation of the insulating properties of the insulator by the adhesive used to bond the foil, since the adhesive layer isn't removed by

the etchant. Bond strengths with this system are not very high and some difficulty has been experienced with delamination. By combining a plating and etching—in which the pattern is plated on with an etch resist metal such as silver or nickel—it is possible to produce plated-through holes and have wiring on both sides of the board.

Stamped wiring—Also widely used, stamped wiring requires a die and is slightly more expensive. The circuit is stamped from foil on the insulator board and simultaneously bonded with a thermoset adhesive. The excess conductor is stripped away. This system allows a greater leeway of materials and the insulator is not degraded by the adhesive or etchant. The pressure and heat from the die gives a good bond strength—from 3 to 8 lb per in. The limitation, of course, is tooling cost and time, but etched tools have been made at low cost.

Embossed wiring—Similar to stamping, embossed wiring is produced by pressing the foil into the insulator, then removing the excess foil mechanically, by grinding. Dies are produced by etching and are not expensive. Chief advantage of this system is that the circuit is flush with the insulator and is adaptable for use in applications such as commutators and switches. The chief disadvantage is the extra step in manufacture—a precision grinding operation.

Painted circuits—This type of circuitry involves painting conductive materials on titanate or steatite wafers. With it, actual circuitry can be produced, including capacitors and resistors. The well known Project Tinkertoy falls into this class. In some configurations the process offers many advantages as far as extreme miniaturization is concerned, and also eliminates a

News Digest

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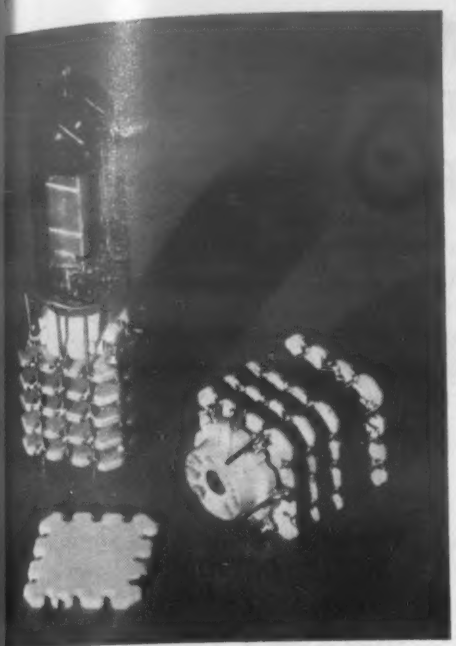

***Project tinkertoy** units utilize painted wiring techniques.*
(National Bureau of Standards Photo)

number of component wiring steps. Disadvantages include the difficulty in repairing a defective circuit, excessive materials costs due to the silver inks used, and a definite practical limitation on the size of the wafers. Project Tinkertoy tends to be unpopular with most engineers. They discount it because it does not succeed well enough in miniaturizing circuits and in reducing weight. Also, part of the resentment to Tinkertoy stems from its presentation as a panacea and final basis for standardization. Many engineers feel that the government has tried to high pressure a system that is not suitable for many kinds of equipment manufacture. In general, it is expected that single wafer printed circuits containing components will be combined with etched or stamped wiring. A great deal of work has been done in standardization of connectors for this use.

Other systems—There are several variations of the techniques described above—powder metal printing techniques, and plated circuitry are sometimes classed separately.

(More News Digest on page 234)

For more information, Circle No. 400 ➤

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continued

Epoxide Resin Use Growing

Interest in the epoxide resins is booming. When first introduced, the epoxies, like many other resins, seemed to have only a few particular specialties, but increased experience in formulation and modification has extended their field of use. Epoxies are now well established as coatings, adhesives, tooling material, and casting resins. More recently, an epoxy molding compound, foams, and paper laminate have been developed that seem to hold promise for a variety of applications. Coupled with the recent price reductions for epoxy resin, these developments hold promise of a greater future for epoxies than many predicted.

New uses

From Minneapolis Honeywell's plastics research laboratory came a report on developments of a molding compound and foam. A paper by Jerome Formo and Luther Bolstad delivered to the recent meeting of the SPE revealed details. The molding compound based on epoxies exhibits the good dimensional stability, heat resistance, high strength and good electrical properties commonly associated with this thermoset material. Although the basic material is more expensive than most common molding compounds there are some applications for which no other material has adequate properties.

Thin sections cast

The epoxy molding compounds become very fluid at molding temperatures and it is possible to produce parts with fragile inserts and extremely thin sections. Molding cycle is between 3 and 5 min, and when parts are re-

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synthetic elastic compositions

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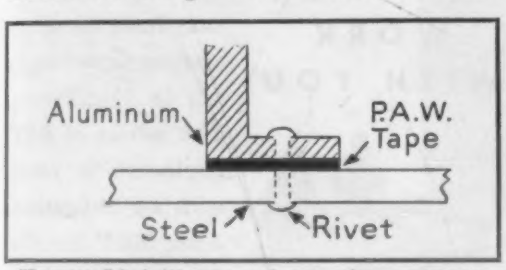
Now Du Pont makes FAIRPRENE of any type rubber coated on any fabric to meet your specifications

"Fairprene" P. A. W. Tape inhibits corrosion, checks joint leaks

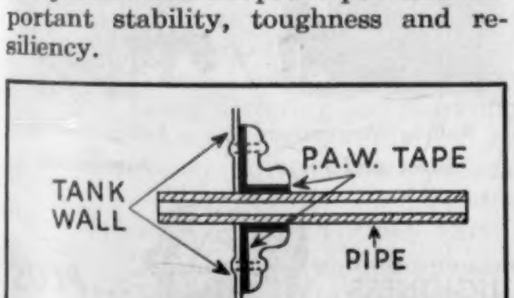
"Fairprene" P. A. W. Tape (Protective and Water-stop) is an example of a coated fabric carefully engineered to do specific jobs. P. A. W. sealing tape is a strong fabric sheeting impregnated and coated with neoprene. Available in three



"Fairprene" P. A. W. tape seals out moisture, prevents electrolytic action at joints where dissimilar metals are involved.

thicknesses, it resists oxidation, action of fresh or salt water, gasoline, oils and greases.

Zinc chromate is present in the adhesive film on P. A. W. unless otherwise specified, and effectively inhibits corrosion when used as a gasket where metals are joined. The neoprene provides important stability, toughness and resiliency.



Correctly applied as part of a properly riveted joint, P. A. W. tape produces a watertight and oiltight seam, eliminating need for caulking in many light metal seams.

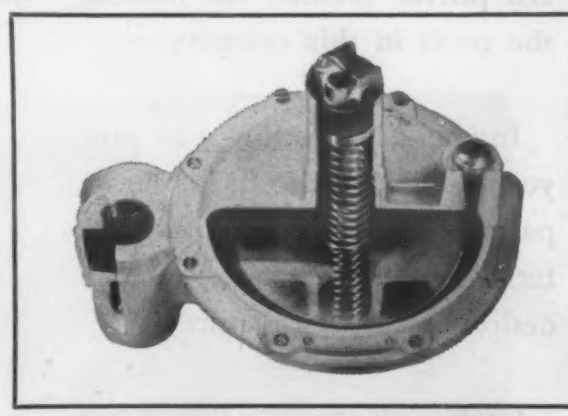
Du Pont engineers are prepared to work with you in applying "Fairprene" P. A. W. tape to your requirements. For further information ask for details on P. A. W. tape when writing for the "Fairprene" booklet offered at right.

Du Pont "Fairprene"* coated fabrics are made by impregnating, spreading or calendering elastic compositions on one or both sides of nylon, ORLON, cotton, glass, felt or other fabrics. These elastic coatings may include (alone or in combination) neoprene, Buna-N, Buna-S, Butyl, Thiokol and silicones.

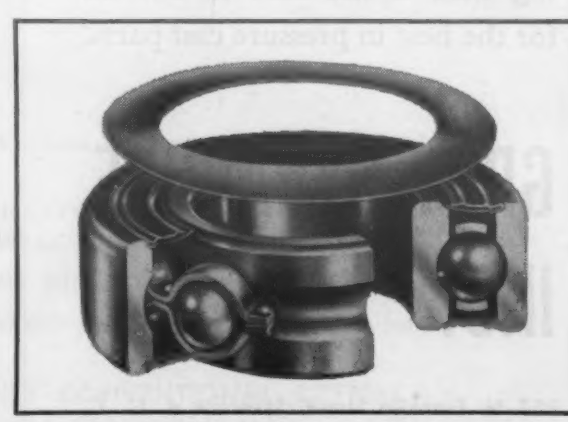
Before selecting a "Fairprene" product, company engineers should first determine the service conditions it will meet. Then Du Pont can develop and test the grade of "Fairprene" best suited for that particular purpose.

Where are "Fairprene" coated fabrics used? They have already proved remarkably successful for sensitive diaphragms, all types of gaskets, apron and protective cloth materials, watertight seam sealants and grease seals and oil-line coverings. In each of these cases Du Pont has applied its engineering experience to the special problems involved. Often, by substituting a "Fairprene" product, manufacturers are able to save many times the value of the part — and continue to save for months by eliminating lost time for replacement.

Specific properties depend, of course, on the end product in mind. Du Pont engineers "tailor" these properties to the particular operating conditions the end product will face. Generally, however, the properties that characterize all "Fairprene" coated fabrics are: resistance to petroleum oils, greases, gasoline and alcohol... to natural aging in air and oxygen ...to heat and cold...to flexing... to action of fresh and salt water.



"Fairprene" diaphragms serve dependably in Rockwell regulator valves for natural, manufactured and liquefied petroleum gases.



SKF Industries, Inc., protects "Red-Seal" bearings from dirt . . . keeps lubricant in—with a seal of Du Pont "Fairprene."

*"*Fairprene" is Du Pont's registered trade-mark for its line of products made from synthetic elastomers available in form of coated fabrics, sheet stocks without fabric insert and adhesives.*

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*City*____________ *State*____________

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continued

moved from the mold, they are slightly soft and can be distorted. Importantly, reheating in an oven causes recovery to mold shape due to plastic memory. Flexibility on removal from mold might simplify die design problems in many cases, perhaps even permitting slight undercuts.

Foams

The epoxy foam formulation was developed for aircraft electronics potting applications. Foaming temperature is between 225 and 250 F with expansion of 8 to 12 times original volume. Compressive strength is 75 psi at a density of 5 to 7 lb per cu ft. A disadvantage in these foams is the high heat of polymerization developed by the resin. Combined with the low thermal conductivity of a foam, the heat generated will char the center section of volumes greater than half a pint. Addition of suitable agents makes the foams self extinguishing.

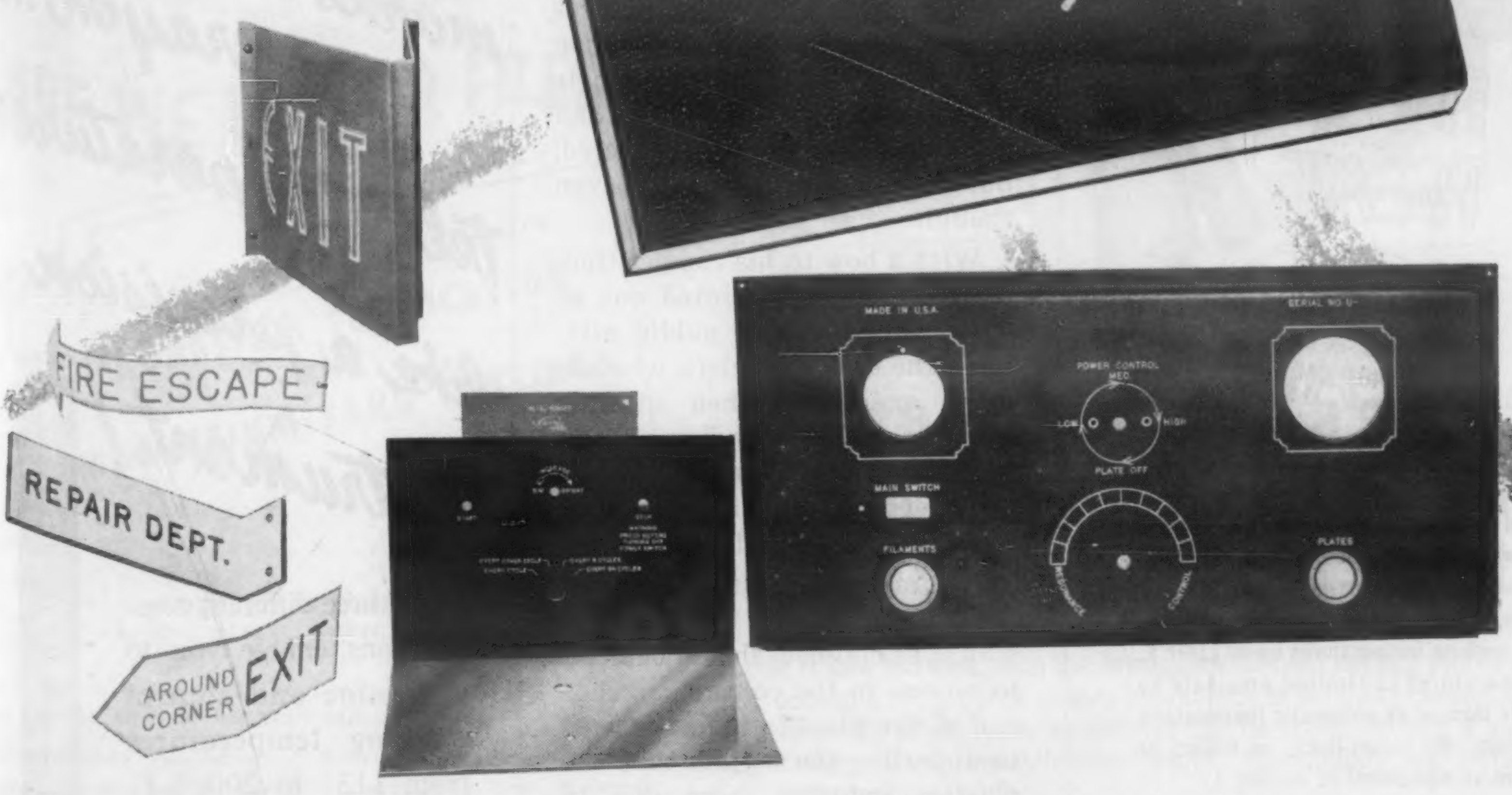
Epoxy paper laminate

The excellent electrical and adhesive properties of epoxies make them particularly suitable for printed circuit use. A new paper based laminate developed by American Printed Circuits Co. is attracting considerable interest since it will resist 95 ASTM arc seconds and has a surface resistivity in the neighborhood of 10^{13} ohms. The water absorption for 24 hr is 0.27%. The material is particularly promising for use in such applications as commutator and switching rings, as it is able to withstand abrasion from brush contacts, unlike many of the more expensive glass-based epoxy boards. The epoxy paper laminate is produced in thicknesses of 1/16 to 1/2 in. with one or two mil copper. Flush printed wiring circuits are also planned for production with various conducting media, including rhodium plated nickel.

(More News Digest on page 238)

AT LAST, an ideal engraving stock

FLEXIBLE
EASY-CUTTING
CHIP-PROOF



HERE IS a truly flexible plastic stock from which even an unskilled operator, using inexpensive tracer-guided engraving equipment, can quickly cut name plates, instrument panels, dials, directional signs and markers of many kinds.

GRAVOFLEX, product of United States Rubber Company, is a laminated "sandwich" of plastic sheeting, the center layer of which is of a contrasting color. When engraved through the outer layer, lettering and marking will stand out permanently on a different color field. Sheets or ready-cut sizes are presently available in a variety of color combinations. Filling engravings with paint is entirely eliminated.

Among other unique advantages, GRAVOFLEX...

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- **REQUIRES ONLY CONVENTIONAL CUTTERS—No need for expensive carbide tools.**
- **CAN BE BONDED TO METAL for shielding of electronic panels.**
- **RESISTS FLAME, moisture and such solvents as white gasoline, solvent naphtha, alcohol, carbon tetrachloride, glycerine, oils, turpentine, animal fats, phenols and cresols.**

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News Digest

continued

"Watch Your Quality" Warns Plastics Exec.

Plastics, by any other name, are better, according to a market research survey conducted for DuPont by Alfred Politz Research. The results of this survey, revealed at the January SPE meeting by Director of Polychemicals Sales, E. F. Schumacher, show that the public holds plastics in low esteem as a class of materials. But some plastics materials known by their trade name—such as Nylon and Bakelite—are not only respected, but are frequently not even thought of as plastics.

With a bow to his competition, Mr. Schumacher pointed out as an example of this public attitude, the case of a clerk who advised against kitchen utensils with "plastics" handles and in the same breath recommended an alternative set because they were made of Bakelite.

Schumacher's point in revealing the results of the survey, which, he claimed, should be news to no one in the consumer goods end of the plastics industry, was to underline the logjam that the plastics industry faces due to past mistakes in materials applications and the consequent loss of reputation and public acceptance of plastics for quality products. He gave the meeting a short appraisal of how plastics got their unsavory reputation and made a strong appeal for a course of positive action to put plastics back on the public list of quality products.

How it happened

Schumacher blamed rapid growth, the small investment needed for production, a sellers' market during which the public would buy anything, and high, quick profit opportunities as the inevitable source of mistakes, misapplications, and low quality. "Now, those mistakes are home to roost in the form of dimin-

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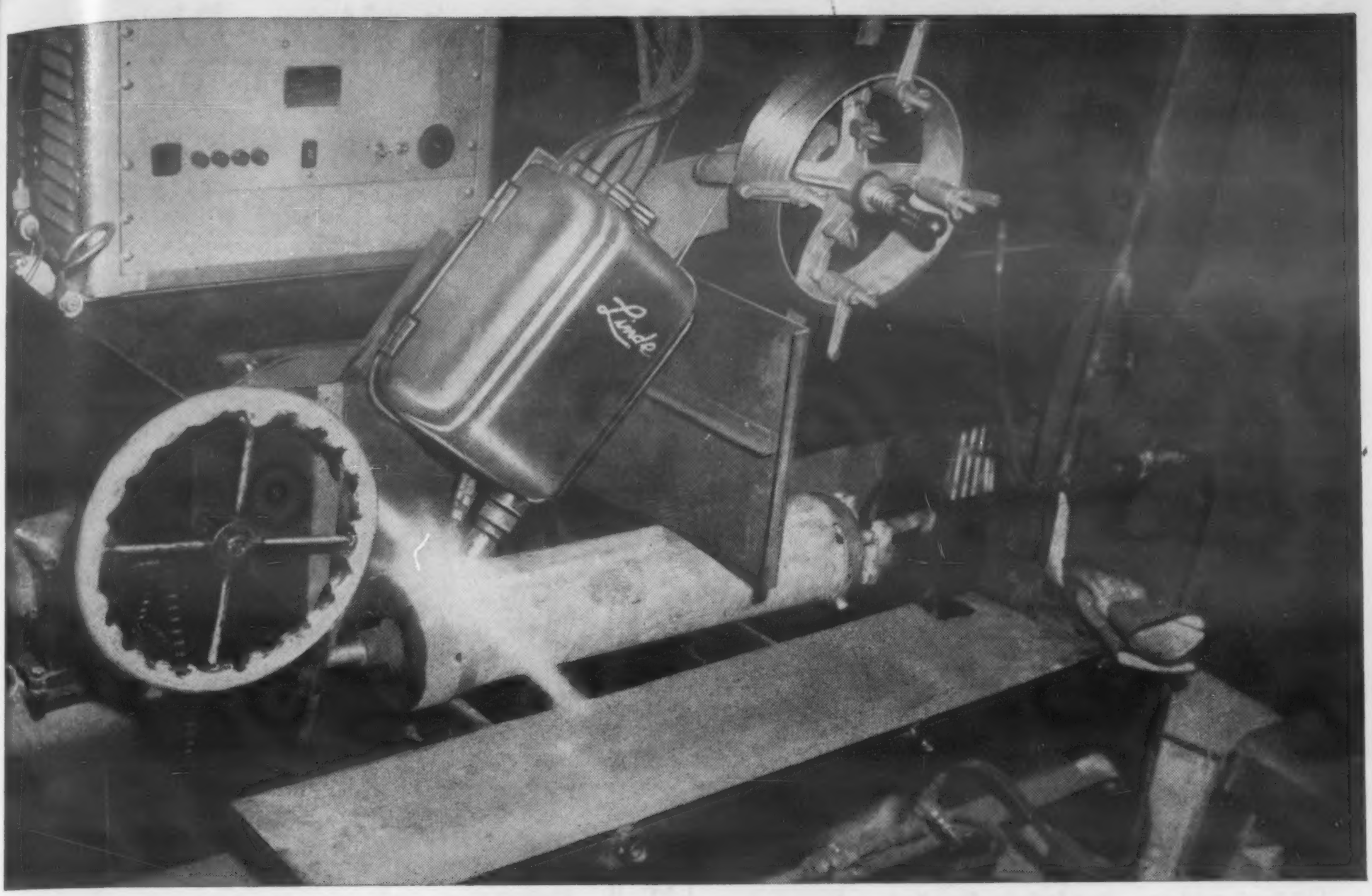
continued

ished public esteem," he said. "Not only that," he added, "our troubles are augmented by new mistakes growing out of the present competitive situation. Such 'mistakes' as skimping on the quality of material in a dish, a household utensil, film, or what have you, are compounded by instances of outright copying of design. The regrettable frequency of these practices indicate the absolute need for somehow getting the industry back on a quality basis."

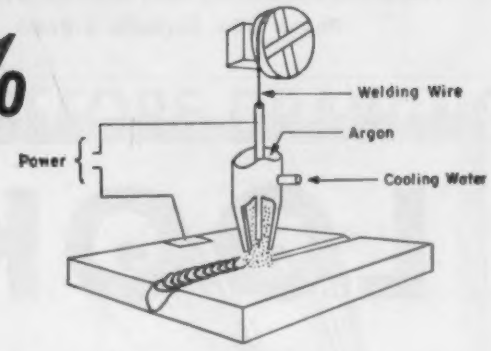
What to do

Schumacher said that the Plastics Materials Committee of the MCA was extremely concerned with the quality problem and had considered instituting a costly public relations campaign. The idea was rejected because the problem was one of getting the industry to actually live up to performance standards rather than making claims that might not stand up. To emphasize this point, Schumacher warned the plastics men, "Emerson said something to the effect that 'What you are thunders so loud, I can't hear what you say.'"

The DuPont executive concluded his talk with an urgent appeal to plastics manufacturers to adhere to the "Statement of Principles by the Plastics Industry" as the only method of upgrading the public's opinion of plastics. This statement of principles affirms: *"Plastics materials challenge industry with new concepts of design, engineering, construction processibility and usefulness. The properties of plastics materials when correctly used open up great new areas of service to the public and industry. Improper use can do irreparable damage to the plastics industry, to both manufacturers and proc-*



Sigma Welding...Cuts Costs 36%
Ups Steel Fabrication 93%



By shifting from manual arc welding to mechanized sigma welding, production of 31-in. long, 11-ga. steel condensers was almost doubled—costs were cut over a third—and unit quality greatly improved. These sigma welded condensers have been tested to hydrostatic pressures of 2,800 lb. per sq. in. with no sign of failure.

All completed condensers are subject to an air pressure test under water, and a supersensitive electronic leak detector . . . Rejects have been practically eliminated by sigma welding. Like many other products throughout industry, these condensers are being fabricated faster and more economically than ever before. Here are some sigma welding features—

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essors of the materials. Therefore, we as manufacturers and processors of plastics materials reaffirm our adherence to the principles upon which the healthy growth of our great industry depends." The statement details an agreement to "understand the properties and limitations of materials," and Schumacher emphasized its importance by warning that the ordinary consumer does not understand the properties of plastics to the same extent he understands natural materials such as glass, leather and wood. For that reason, he warned, plastics manufacturers must be particularly wary of making false claims or exaggerated promises. Unless such care is taken, and continued, there are bound to be repetitions of such damaging occurrences as the widely circulated editorial in the Chicago Tribune entitled "Plastics—Phooey!"

SPE Discusses Plastics Progress

Technological developments in the plastics industry were aired before a record audience at the 1955 meeting of the Society of Plastics Engineers. Fluorocarbons, as one of the fastest developing basic resins, got special attention in both papers and special panels. Other materials and techniques were far from ignored, and important developments were revealed in the field of epoxies, reinforced materials, isocyanates, Durestos, organic finishes, and others.

Polyethylene

Polyethylene, as the fastest growing of all basic resins, was analyzed from a marketing standpoint by E. S. Childs of Monsanto Chemical Co. He maintained that lower costs and better raw materials were in store as a result of the number of basic resin suppliers increasing from the two at present to eight to ten in the near future.

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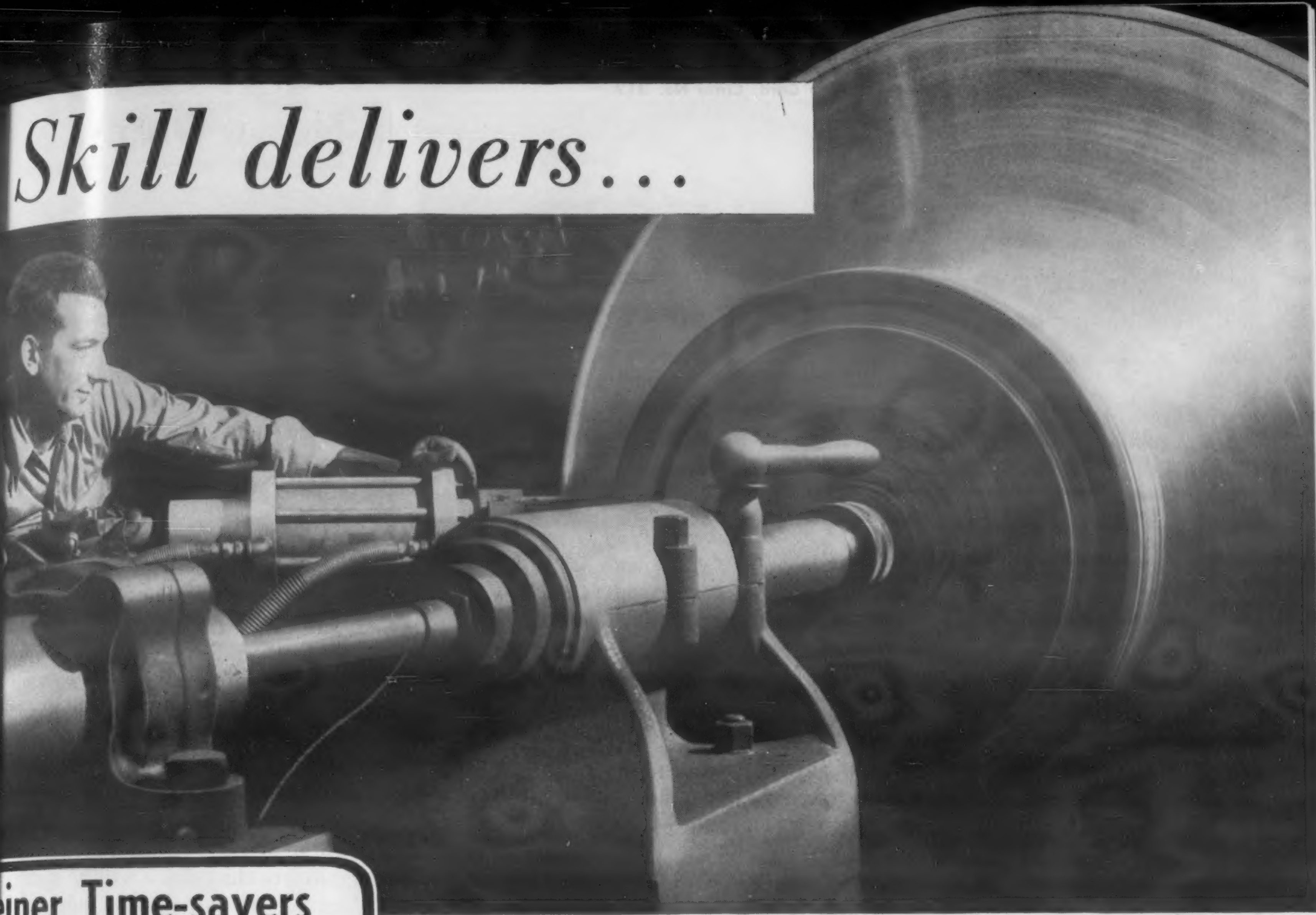

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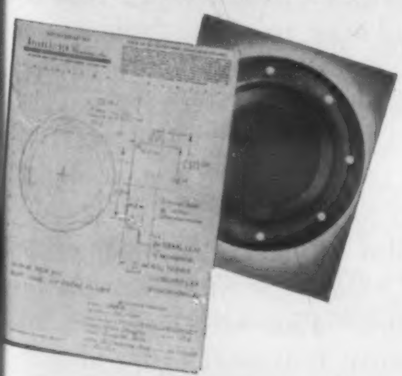

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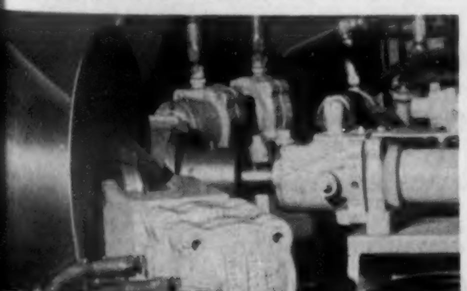

DROFORMING

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million pounds in 1953 to over 200 million pounds in 1954, Mr. Childs presented his projection for future demands in various markets. For bottle prospects he foresaw an ultimate figure of 59 million pounds, for coatings, 55-60 million pounds, and for film, which he believed the most difficult to predict due to the growing number of uses, he forecast a total potential in the range of 300 million pounds. Markets now developing indicate a demand for over 65 million pounds of polyethylene pipe, and a foreseeable 60 million pounds for cable and wire insulation. Wax additives, not a direct concern of plastics men, may consume up to 15 million pounds. The totals which add up to over 550 million pounds, indicate that there will be a market for the 600 million pounds of polyethylene capacity which has been planned by resin manufacturers for 1957. Childs warned that it was highly unlikely that use and production capacity would stay in phase from a short range standpoint, and that periods of relative scarcity and glut could be expected. However, the long range gamble appeared likely to pay off.

John Labelle, President of the SPE, told the audience in his keynote address that the low pressure polymerization of polyethylene and the possibility of radiation polymerization of both monomer and polymer held great promise for production of the raw materials.

New intermediates

Isocyanates—the intermediates which react with a wide variety of compounds—also attracted considerable interest at the meeting. This material, which has been exclusively imported up until the present time, is now being produced in quantity in the United States and promises to play an important part in the foam industry—particularly in competition with the rubber foams. Polyurethane foams range from rigid to very flexible and

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have several unique properties, which are covered in a feature article elsewhere in this issue.

The fluorocarbon resins received a large amount of discussion time, being the subject of several papers and a special panel session. Fluorocarbon based lubricants were revealed to have special properties that indicated their use in such applications as nitric acid and high pressure oxygen equipment. Teflon reinforced silicone rubbers were discussed by George Irby of General Electric, and were revealed to have high physical properties while remaining flexible and rubbery. The material is limited to compression molding techniques.

The first paper in this country on the subject of the British developed asbestos reinforced phenolic Durestos was delivered by W. E. Braham of Zenith Plastics. The material is widely used for aircraft and missile structures in England, and with the increasing availability of asbestos fibers here, it holds promise as an important molding material.

Westinghouse Opens Steam Power Lab

A six million dollar research facility for long range and applied development work on steam and gas turbines for power generation has been opened by Westinghouse Electric Corp. The large investment in research facilities is believed justified by two main factors: first, the electrical generating capacity of the United States, if it merely follows the rate of development of the last ten years, will double by 1965, requiring existing facilities to be duplicated by new equipment, a market that will be further enlarged by replacement of obsolete generating plants. Secondly, the greater efficiency of steam power generation now

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required implies constantly increasing temperatures, pressures and turbine sizes. New equipment capable of operating at pressures above 5000 psi and temperatures in the softening range of conventional steels requires new materials and new design concepts.

The giant step from 2400-psi steam pressure to above the critical pressure of 3206-psi absolute is now being taken in a design for a 275,000-kw generator that will operate at 5000-psi gage and 1150 F. By going well into the superpressure region, control problems encountered at critical pressure are sidestepped. However, operating in the superpressure region brings many new problems.

Gas turbines

Westinghouse Engineering Manager, J. R. Carlson, expects the gas turbine to win much greater acceptance as a power generating source in the next few years. Because of its light weight, low cooling water requirements, increased output at low ambient temperatures, and quick starting characteristics, Carlson believes that the gas turbine will be a major contender for plants in the 1000 to 15,000-kw range. The new Westinghouse laboratory is equipped to do development work on combustion and turbine design for gas turbines for more general applications than those for which they are now employed.

Future for steam

The new steam laboratory was developed with full acceptance of the fact that a growing amount of power is likely to come from nuclear sources within the next ten years. This implies no shift away from steam and turbines, however, since the steam cycle is the only known way to translate the heat generated in nuclear reactions into electrical power.